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CAMEVAL-2002 Land Forces Signature Reduction Trial:

Ground Truthing, Calibration and Multi-Sensor Data Acquisition for DRDC Experiments

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Defence R&D Canada - Ottawa

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Abstract

The CAMEVAL-2002 Land Forces Signature Reduction (LFSR) trial was conducted at the Canadian Forces Base (CFB) Petawawa in June 2002. For the LFSR trial, 27 military vehicles (primarily Leopard C2 tanks and Coyote reconnaissance vehicles) were deployed under forest canopy, along tree lines and in open field. A subset of the Leopards and Coyotes was deployed with a trial camouflage screen, another subset was covered with the current in-service camouflage, and a final subset was left uncovered. During the LFSR trial, Defence Research and Development Canada (DRDC) Ottawa and DRDC Valcartier acquired airborne and spaceborne Synthetic Aperture Radar (SAR) imagery and airborne Hyperspectral Imagery (HSI) data over the trial sites, and conducted extensive calibration and ground truthing activities in support of these acquisitions. This report documents the SAR and HSI data acquisition, ground truthing and calibration activities completed during the trial, thereby providing the foundation for any future analyses that use these multi-sensor data. This report also describes the five DRDC Ottawa and DRDC Valcartier analyses that were planned at the time of the trial.

Résumé

L'essai de réduction de la signature des forces terrestres CAMEVAL-2002 a été réalisé à la base des Forces canadiennes (BFC) de Petawawa en juin 2002. Pour cet essai, 27 véhicules militaires (principalement des chars d'assaut Leopard C2 et des véhicules de reconnaissance Coyote) ont été déployés sous la voûte forestière, le long des limites des arbres et en plein champ. Un sous-groupe de Leopard et de Coyote a été déployé avec un écran de camouflage à l'essai, un autre sous-groupe a été déployé avec le camouflage qui est utilisé actuellement, et un dernier sous-groupe a été déployé sans écran de camouflage. Pendant l'essai de réduction de la signature des forces terrestres, le Recherche et Développement pour la défense du Canada (RDDC) – Ottawa et le RDDC – Valcartier ont relevé des données d'imagerie de radar à antenne synthétique (SAR) aéroporté et spatial, et des données de capteurs d'imagerie hyperspectrale (HSI) aéroportés sur les sites d'essai, et ils ont réalisé des activités prolongées d'étalonnage et de vérifications au sol pour appuyer les données relevées. Ce rapport étaye les relevés de données SAR et HSI ainsi que les activités d'étalonnage et de vérifications au sol réalisées au cours de la mise à l'essai, fournissant ainsi les fondements de toutes les analyses futures utilisant les données multicapteurs. Ce rapport décrit aussi les cinq analyses du RDDC – Ottawa et du RDDC – Valcartier qui étaient prévues au moment de l'essai.

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Executive summary

The CAMEVAL-2002 Land Forces Signature Reduction (LFSR) trial was organised by the Director Soldier System Program Management (DSSPM) and Director Land Requirements (DLR) to assess the effectiveness of a trial camouflage screen that provides camouflage in the Visible and Near-Infrared (VNIR) and Thermal Infrared (TIR) wavelengths and at radar frequencies. Defence Research and Development Canada (DRDC) Ottawa and DRDC Valcartier worked in collaboration with DSSPM and DLR to establish an experiment that would permit the assessment of the trial camouflage screen against Synthetic Aperture Radar (SAR) and Hyperspectral Imaging (HSI) sensors. The LFSR trial was conducted at the Canadian Forces Base (CFB) Petawawa in June 2002. There were 10 Leopard C2 tanks, 10 Coyote reconnaissance vehicles and seven other military vehicles deployed with variables including degree of concealment (under forest canopy, along tree lines or in open field) and type of cover (trial camouflage screen, current in-service camouflage, thermal blanket, or bare).

During the LFSR trial, DRDC Ottawa acquired airborne X-band and polarimetric C-band SAR data using the C/X-SAR on Environment Canada's Convair-580, and spaceborne C-band SAR imagery using Canada's RADARSAT-1 satellite. DRDC Valcartier acquired airborne HSI data in the Short-Wave Infrared (SWIR) spectral region using the SFSI-II sensor, owned by the Canada Centre for Remote Sensing (CCRS) and operated by Borstad and Associates. DRDC Ottawa and DRDC Valcartier also conducted an extensive ground truthing and calibration campaign in support of these data.

This report documents the SAR and HSI data acquisition, ground truthing and calibration, thereby providing the foundation for any future experiments that use these multi-sensor data. The data acquisition description includes the aircraft and sensor parameters for each acquisition. The ground truthing description includes results of positional surveys conducted using various Global Positioning System (GPS) receivers, ground and airborne photography of the deployed targets and surrounding environments, event logs recorded during data acquisition, and soil moisture measurements taken in advance of the SAR acquisitions. The calibration description includes the layout of the SAR and HSI calibration sites, and the tabulated values of the orientation angles of the SAR calibration equipment as a function of SAR flight line. This report also describes the experiments that were planned at the time of the trial, including the effect of the trial camouflage screen on the Radar Cross Section (RCS) of the covered vehicles, on HSI target detection, and on the efficiency of Automatic Target Recognition (ATR) algorithms.

Secker, J., English, R., Yeremy, M. and Lévesque, J. 2002. CAMEVAL-2002 Land Forces Signature Reduction Trial: Ground Truthing, Calibration and Multi-Sensor Data Acquisition for DRDC Experiments. DRDC Ottawa TM 2002-121. Defence R&D Canada - Ottawa.

Sommaire

L'essai de réduction de la signature des forces terrestres CAMEVAL-2002 a été organisé par le Directeur - Administration du programme de l'équipement du soldat (DAPES) et le Directeur – Besoins en ressources terrestres (DBRT) pour évaluer l'efficacité d'un écran de camouflage à l'essai qui fournit une protection dans les longueurs d'ondes visibles et proche infrarouge (VNIR), et infrarouge thermique (TIR), et dans les fréquences radar. Le Recherche et Développement pour la défense du Canada (RDDC) – Ottawa et le RDDC – Valcartier ont travaillé en collaboration avec le DAPES et le DBRT à la mise en place d'une expérience permettant d'évaluer l'efficacité de l'écran de camouflage à l'essai contre le radar à antenne synthétique (SAR) et les capteurs d'imagerie hyperspectrale (HSI). L'essai de réduction de la signature des forces terrestres a été réalisé à la base des Forces canadiennes de Petawawa en juin 2002. On a déployé 10 chars d'assaut Leopard C2, 10 véhicules de reconnaissance Coyote et 7 autres véhicules militaires en utilisant diverses variables, dont différents degrés de dissimulation (sous la voûte forestière, le long des limites des arbres et en plein champ) et différents types de camouflages (écran de camouflage à l'essai, le camouflage actuellement utilisé, couverture thermique, ou aucun dispositif de camouflage).

Pendant l'essai de réduction de la signature des forces terrestres, le RDDC – Ottawa a relevé des données de radar SAR aéroporté en bande X et en bande C polarimétrique au moyen du radar SAR C/X monté sur le Convair-580 d'Environnement Canada, et des données d'imagerie SAR en bande C spatiale captées au moyen du satellite canadien RADARSAT-1. Le RDDC – Valcartier a relevé des données de capteurs HSI aéroportés dans le domaine spectral de l'infrarouge de courte longueur d'onde (SWIR) au moyen du capteur SFSI-II, qui appartient au Centre canadien de télédétection (CCT) et qui est exploité par Borstad and Associates. Le RDDC – Ottawa et le RDDC – Valcartier ont aussi effectué des activités de vérifications au sol et d'étalonnage prolongées en vue d'appuyer ces données.

Ce rapport étaye les relevés de données SAR et HSI, ainsi que les activités d'étalonnage et de vérifications au sol réalisées au cours de la mise à l'essai, fournissant ainsi les fondements de toutes les analyses futures utilisant ces données multicapteurs. La description des relevés de données comprend les paramètres de l'aéronef et du capteur pour chaque relevé. La description des vérifications au sol comprend les résultats de relevés de position réalisés au moyen de divers récepteurs de systèmes de positionnement global (GPS), de photographies aériennes et au sol des objectifs déployés et du milieu environnant, les données des journaux des événements enregistrés pendant le relevé des données, et les mesures de l'humidité du sol prises avant le relevé des données SAR. La description de l'étalonnage comprend le plan des sites d'étalonnage SAR et HSI, ainsi que les valeurs tabulées des angles d'orientation du matériel d'étalonnage du SAR comme fonction de l'axe de passage SAR. Ce rapport décrit aussi les expériences qui ont été prévues au moment de cet essai, y compris celles sur l'effet des écrans de camouflage à l'essai sur la section efficace radar (RCS) des véhicules camouflés, sur la détection des objectifs HSI et sur l'efficacité des algorithmes de reconnaissance automatique des objectifs.

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We would like to extend out thanks to Mr. Mike Boyle, Mr. Lloyd Gallop, Dr. Julian Meng, Mr. Terry Potter, Mr. David Schlingmeier, Mr. Mike Seymour and Dr. Jacques Tremblay for support with ground truthing and calibration during the trial. As well, we would like to thank Ms. Janice Lang and Mr. Steen Larsen (Danish Defence Research Establishment) for their ground and aerial photography of the deployed vehicles and their environment, and Dr. Christoph Gierull and Mr. Jason Norris for their comments on the manuscript.

Map images used in this document were generated by scanning the map "CFB Petawawa", Series A702, Map MCE 132, Edition 8, which was produced by the Mapping and Charting Establishment (MCE), Department of National Defence, Canada © 1999.

1. Introduction

The CAMEVAL-2002 trial was conducted at the Canadian Forces Base (CFB) Petawawa, Ontario, during the period 3 – 14 June 2002 [3,4]. The Trial Co-ordinator was Mr. R. Balma from the Director Soldier Systems Program Management (NDHQ DSSPM CCD), and the Trial Director was Major R. Walker from the Director Land Requirements (DLR 7-5/J3 Engr Ops 4-5). There were several trials being conducted during CAMEVAL-2002, both national and NATO. They were:

1. DSP 00002093 Land Forces Signature Reduction
2. DLR Anti-Intrusion Detection System
3. NATO SCI-095 Reduction of Soldiers Signature
4. NATO SCI-096 Enhancement of Camouflage Assessment Techniques

In the document that follows, only the Land Forces Signature Reduction (LFSR) component (Land Forces Project 0002093) of the CAMEVAL-2002 trial will be discussed, and it will be referred to as the LFSR trial.

The LFSR trial was organised for the purpose of measuring the effectiveness of a trial camouflage screen that provides camouflage in the Visible and Near-Infrared (VNIR) and Thermal Infrared (TIR) wavelengths and at radar frequencies. The effectiveness of this trial screen will be compared to the current in-service net, which has a different colour pattern and is ineffective at radar frequencies or TIR wavelengths.

DSSPM defined four primary thrusts in advance of the LFSR trial. These were:

1. Effectiveness testing of new visible large-scale patterns on new camouflage screens.
2. Assessment of camouflage screen effectiveness against airborne and satellite C- and X-band Synthetic Aperture Radar (SAR) sensors and airborne Hyperspectral Imaging (HSI) sensors.
3. Assessment of camouflage screen effectiveness against mid- and long-wave thermal imagers.
4. Assessment of camouflage screen effectiveness against visible satellite imagery (both multi-spectral and panchromatic).

Scientists within Defence Research and Development Canada (DRDC) Ottawa and DRDC Valcartier worked in collaboration with DSSPM / DLR to perform the assessment of camouflage screen effectiveness against SAR and HSI sensors. In addition to these assessment experiments, DRDC Ottawa and DRDC Valcartier defined four other experiments

to leverage from the LSFR trial. These are defined fully in Section 4. Briefly, these experiments are:

1. Evaluation of the effect of camouflage on target recognition algorithms.

2. Evaluation of the improvement to target detection algorithms with the fusion of SAR and HSI data.

3. Assessment of polarimetric interferometric SAR (Pol-InSAR) techniques for target detection and Ground Moving Target Indication (GMTI).

4. Assessment of spectral unmixing and bi-directional reflectance correction algorithms for HSI data.

The LFSR trial was designed to have nine military vehicles deployed at each of two sites: Site 1 was at the edge of a coniferous forest, and Site 2 was at the edge of a deciduous forest (Figure 1). Both of these forest sites border on ranges that are clear of trees, and were selected for their homogeneous and well-studied tree lines. At these two sites, the vehicles were deployed in groups of three: three along the tree line, three in the open field, and three under the forest canopy. Within each subgroup of three vehicles, the idea was to have one vehicle covered with the in-service camouflage netting, and one or both of the remaining vehicles covered with the new (trial) camouflage screens. In this manner, comparisons could be made between the two types of camouflage for vehicles deployed in similar surroundings.

In addition to these 18 vehicles, the LFSR trial included nine vehicles deployed at a third site (Site 3 in Figure 1). These nine vehicles were all bare, and they were used to assist in the analysis of the SAR imagery. Overall, there were 27 military vehicles deployed: 10 Leopard C2 tanks (LEOs), 10 Coyote reconnaissance vehicles (COYs), and seven others. There were six under forest canopy, six along the tree line, and 15 in the open. Of these vehicles, there were 14 with camouflage netting systems installed. All vehicles were in place by 1700 hours on Wednesday 5 June, and they remained fixed in place until the afternoon of Thursday 13 June, at which time their removal began. This removal was completed early on the Friday morning.

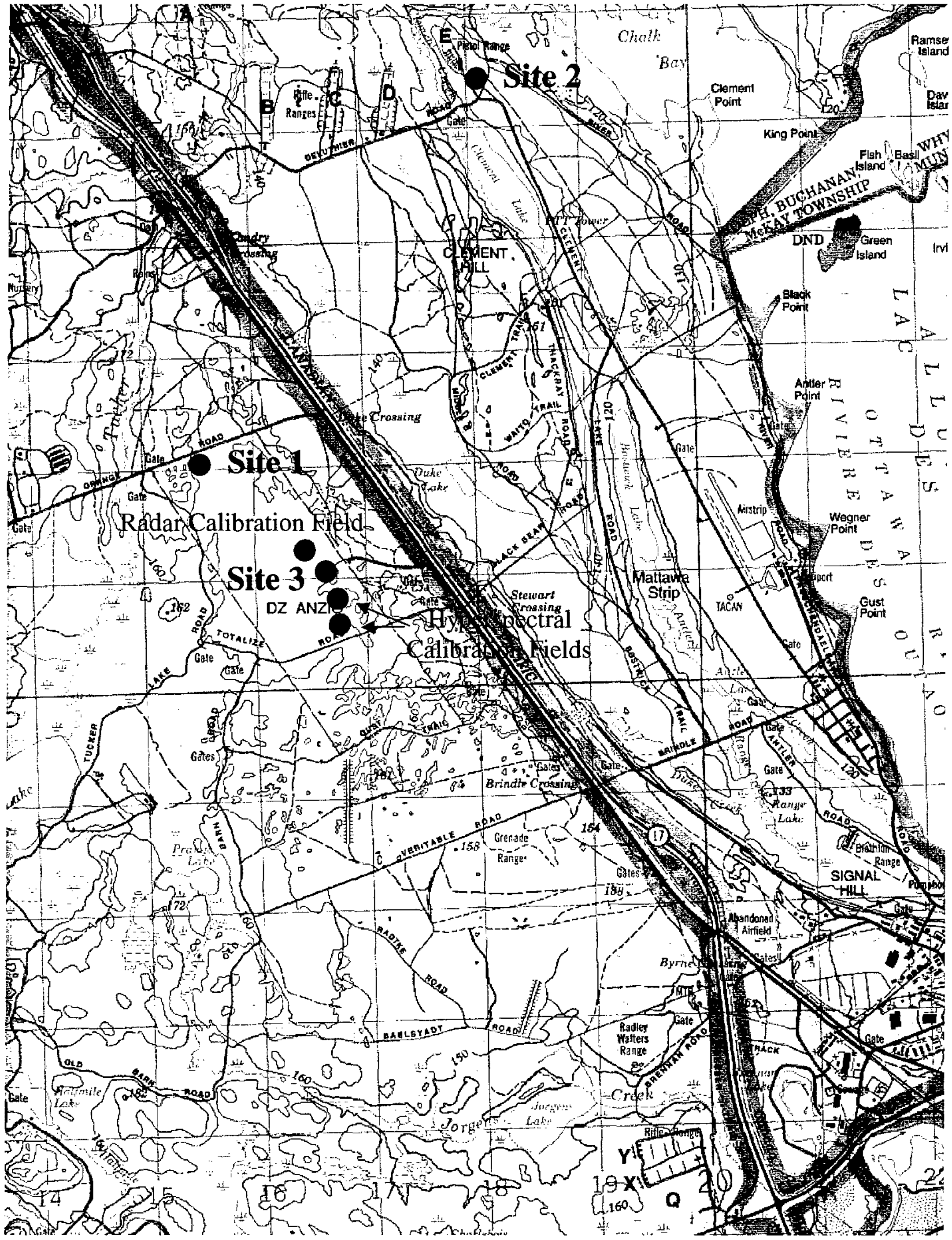

Figure 1. Map of CFB Petawawa showing approximate locations of LFSR sites.

DSSPM was responsible for effectiveness testing of the visible large-scale patterns on the new camouflage screens. To compare the patterns and colours of the camouflage screens against the forest canopy, DSSPM acquired well-calibrated multi-spectral imagery (throughout the VNIR and Thermal Infrared – TIR – spectral ranges, as well as panchromatic imagery [1]. In addition, DSSPM held Observer Trials at both deployment sites. The purpose of these trials was to quantify the difference between the in-service screen and the trial camouflage screen. For these trials, DSSPM delimited four vehicle slots along each tree line, using five standard size sheets (4 ft x 8 ft) of white-painted plywood. Three of the slots contained a camouflaged vehicle, but the fourth slot was empty. Beginning at a distance of 3000 m, a group of observers, with no previous knowledge of the scene and unaided by binoculars, individually viewed the tree line deployment and judged which of the four slots contained a vehicle. The observers moved towards the vehicles in 100 m increments, and at each stop they again judged which of the four slots contained a vehicle. At the farthest distances from the vehicles, the estimates of vehicle location were little better than a guess, even for those with good visual acuity. However, at lesser distances, the observers began to discern a difference between the forest canopy and the camouflage screening, and were able to correctly position a camouflaged vehicle in one of the slots.

The Royal Canadian Dragoons (RCD) and Second Regiment, Royal Canadian Horse Artillery (2 RCHA), units of the Second Canadian Mechanized Brigade Group (2CMBG) at CFB Petawawa, were tasked to support the LFSR trial. They completed the survey for position and location, deployed the vehicles and camouflage, established the Command Post (CP) and security pickets, and participated in the Observer Trials.

Scientists within DRDC Ottawa and DRDC Valcartier assessed the effectiveness of the camouflage against SAR and HSI sensors. The Aerospace Radar and Navigation Section within DRDC Ottawa conducted experiments designed to measure the reduction in X- and C-band Radar Cross Section (RCS) for vehicles covered by the camouflage. Both airborne and spaceborne SAR imagery data were acquired. The airborne SAR data were single channel X-band and fully polarimetric C-band imagery, with a resolution of 1 m in azimuth and 6 m in slant range. The spaceborne imagery was acquired using Canada's RADARSAT-1 satellite, which in this case delivered single-channel C-band imagery with a resolution of approximately 8-m by 8-m. To support the SAR imagery acquisition, calibration and other support equipment was deployed at the SAR Calibration Site (Figure 1). This equipment was in place by the evening of Tuesday 4 June, and it was removed by the evening of Saturday 8 June. During that time, the equipment was stationary, but the orientation of some calibration equipment changed between image acquisitions.

The Space Optronics Section within DRDC Valcartier used two HSI sensors to compare the efficiency of the trial screens with the in-service camouflage netting. The two sensors were flown onboard a Beaver floatplane at two different altitudes. The primary HSI sensor acquired 240 bands throughout the short-wave infrared (SWIR) wavelengths (1200 to 2400 nm), with a 2-3 m spatial resolution. A secondary HIS sensor acquired 4 to 9 bands, depending on the altitude flown, throughout the VNIR wavelengths, with a 2-3 m spatial resolution. Both sensors were flown at 1.83 km (6000 feet) and 2.90 km (9500 feet) at three different times. To support the HSI data acquisition, calibration targets and other experiments were deployed at the two HSI Calibration Sites (Figure 1). This equipment was in place by the evening of Wednesday 5 June, and was removed on Saturday 8 June.

To support analysis of the DRDC Ottawa and DRDC Valcartier SAR and HSI data, 676 photographs were taken (both on the ground and from the air) during the LFSR trial. In addition, DRDC Ottawa tasked the Mapping and Charting Establishment (MCE) section of J2 Geomatics Imagery and Counter Intelligence (J2/GICI) to perform a complete positional ground truthing of most deployed targets and calibration equipment. MCE used Real Time Kinematic (RTK) Global Positioning System (GPS) receivers to obtain these measurements during the morning of Wed 5 June. DRDC Ottawa also performed positional ground truthing using differential and hand-held GPS units, but in general these do not provide as high a degree of accuracy as the RTK measurements.

This report describes the LFSR trial, and it documents the SAR and HSI data acquisition, ground truthing and calibration activities conducted by DRDC Ottawa and DRDC Valcartier. It also describes the SAR and HSI experiments that were conducted by DRDC Ottawa and DRDC Valcartier. In Sections 2 and 3, the deployment of vehicles and calibration equipment is described. In Section 4, the DRDC experiments involving SAR and HSI sensors are described. Note that analysis and results of these experiments will be reported elsewhere. In Section 5, the acquisition of airborne and spaceborne SAR and HSI data is described, and in Section 6, several ground truthing activities are described.

2. Site Layout and Vehicle Deployment

Activity during the LFSR trial was restricted primarily to the northern half of the Drop Zone (DZ) Anzio plain (north of Totalize Road) and the northern tip of the Mattawa Plain. In total, there were 27 military vehicles deployed, with nine at each of Sites 1, 2 and 3. The locations for Sites 1 and 2 were selected because of forest type and its density along the tree lines. Site 3 was chosen because of its proximity to the DZ Anzio Observation Hut (used as the Trial Headquarters), and its location on the open plain.

The approximate locations for Sites 1, 2 and 3 are illustrated in Figure 1, with the approximate centre coordinates taken from the "Plan of Trial" document [3]. These five sites are described further in Sections 2.1 – 2.5.

2.1 Site 1: DZ Anzio Plain

Site 1 straddles Orange Road along the northern edge of the DZ Anzio plain. This location was selected as the best site for comparison of the visible camouflage pattern against a coniferous canopy. Here, the transition between open plain and the forest is abrupt, with the tree line beginning on the north side of Orange Road. The DZ Anzio plain is relatively flat in this vicinity, and it consists mostly of grasses and scrub brush partially covering a very sandy soil. In many areas, the sand was exposed, and in some areas, primarily along the eastern edge of the plain (from Site 1 down to Site 3), the sand had blown and accumulated into dunes. The positions for targets deployed at Site 1 are shown in Figure 2.

Site 1 had three subsites: 1A was along the coniferous tree line, 1B was north of Orange Road and within the forest, and 1C was in the open field. At Site 1A, there was a strip of grass a few meters wide, between the gravelled surface of Orange Road and the tree line. The vehicles were backed up to the tree line, and the camouflage was deployed for optimal comparison against the dense canopy. Note that the vehicles at Site 1A were in adjacent slots for the DSSPM Observer Trial, and that the empty slot was the most eastward one. Site 1B was located just east of Tucker Lake Road, and there were openings of significant size in the canopy in the vicinity of the deployed vehicles. In fact, the vehicle at position B3 was not camouflaged and was deployed under the branches of a single tree. As a result, it will likely be visible in the SAR imagery from several different azimuth angles.

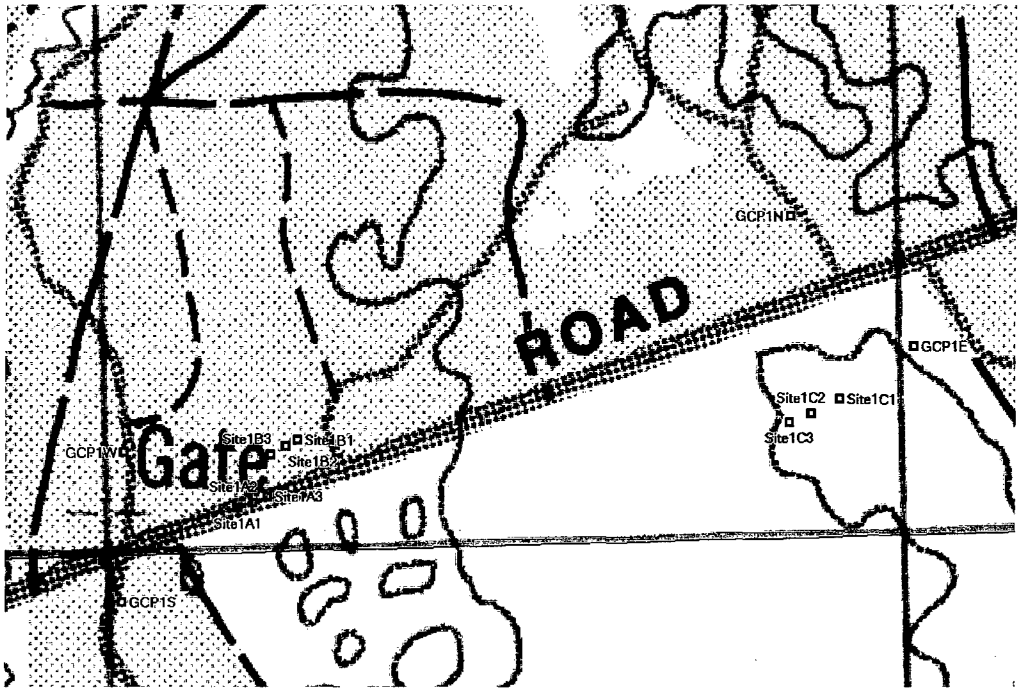

Figure 2. GPS locations of vehicles and Ground Control Points at Site 1.

a. Site 1 - ANZIO

	1	2	3
1. Subsite B	COY CA2 CA3	COY CA1	COY Bare
2. Subsite A.	COY CA2	COY CA1 CA3	COY CA2
3. Subsite C.	LEO CA2 CA3	LEO Bare CA3	LEO CA1

Figure 3. Deployment of target vehicles at Site 1.

Site 1C was offset to the east from 1A and 1B to accommodate the DSSPM Observer Trial, which required an unobstructed view of site 1A from the south, along the western edge of the range. As is illustrated in Figure 4, the ground around the vehicles at site 1C was mostly bare sand: about 80 percent sand and 20 percent grass cover. The elevation at this site was slightly higher than that of 1A and 1B due to the accumulation of sand in dunes at the eastern edge of the range.

Each of sites 1A, 1B and 1C had three vehicles of the same type, separated by at least 30 m, and oriented at 130°. COYs were deployed at sites 1A and 1B, and LEOs were deployed at site 1C. Figure 3 was copied from the Plan of Trial document, and illustrates (for the grid of subsite 1A/1B/1C versus position 1/2/3) which types of camouflage (if any) was used and whether a thermal blanket was used. In this figure, CA1 designates the in-service camouflage net, CA2 designates the trial camouflage screen, and CA3 designates the thermal blanket. All vehicles were deployed stripped of their combat load. In Figure 4, aerial photographs of sites 1A, 1B and 1C illustrate the immediate surroundings of the deployed vehicles, as described above. In Figure 5, ground photographs illustrate the deployed vehicles, for the same grid of subsite 1A/1B/1C versus position 1/2/3.

Note that in the Plan of Trial document [3], vehicles in sites 1A, 1B and 1C were given positions numbered 1, 2 and 3 from left to right. During the actual deployment, the relative orientation between subsites was not maintained. At subsite A, position 1 was the most westward, while at subsites B and C, position 1 was the most eastward.

2.2 Site 2: Mattawa Plain

Site 2 was located along the northern end of the Mattawa plain, straddling Deluthier Road between Clement Road and River Road. This location was selected as the best site for comparison of the visible camouflage pattern against a deciduous canopy. As in Site 1, the transition between open plain and the forest was abrupt, with the tree line beginning on the northwest side of Deluthier Road. The Mattawa plain at Site 2 was very flat, with the exception of shallow but extensive scarring (Figure 4) from tracked-vehicle manoeuvres. Here, the Mattawa plain had grasses and scrub brush partially covering a very sandy soil. The positions for targets deployed at Site 1 are shown in Figure 6.

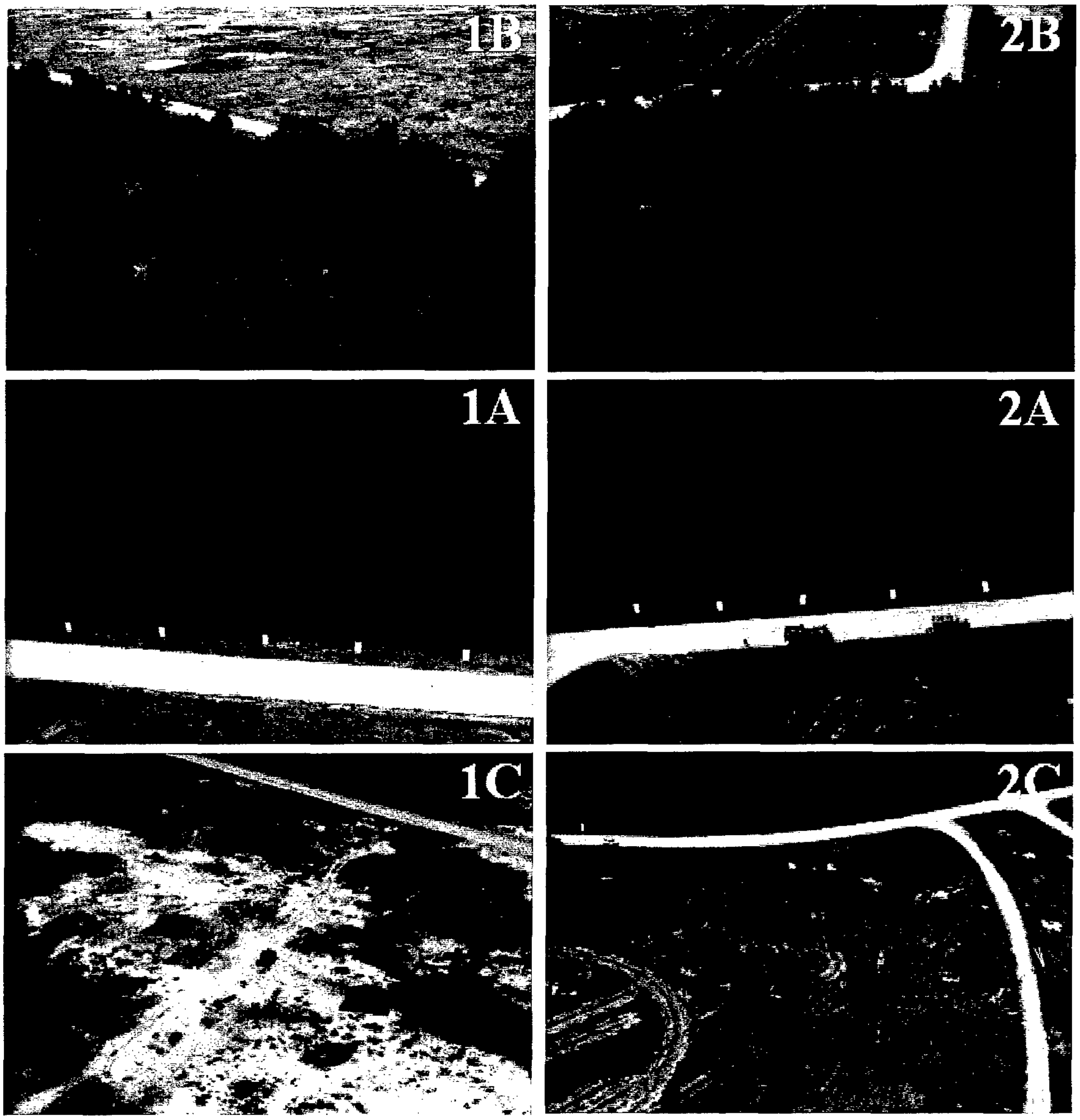

Figure 4. Overhead views of Sites 1B, 1A and 1C, and 2B, 2A and 2C.

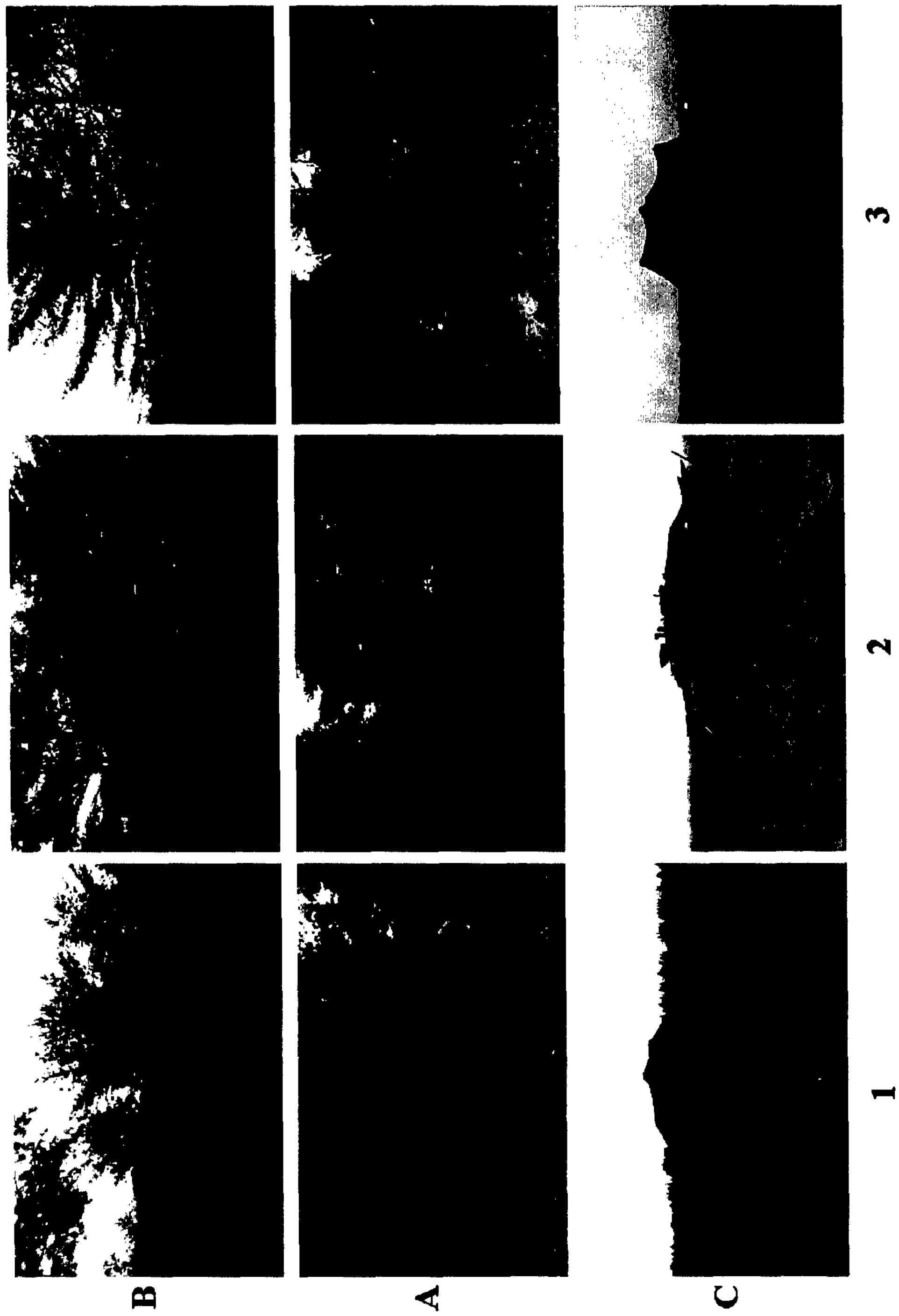

Figure 5. Vehicles deployed at Sites 1B, 1A, and 1C in positions 1, 2 and 3.

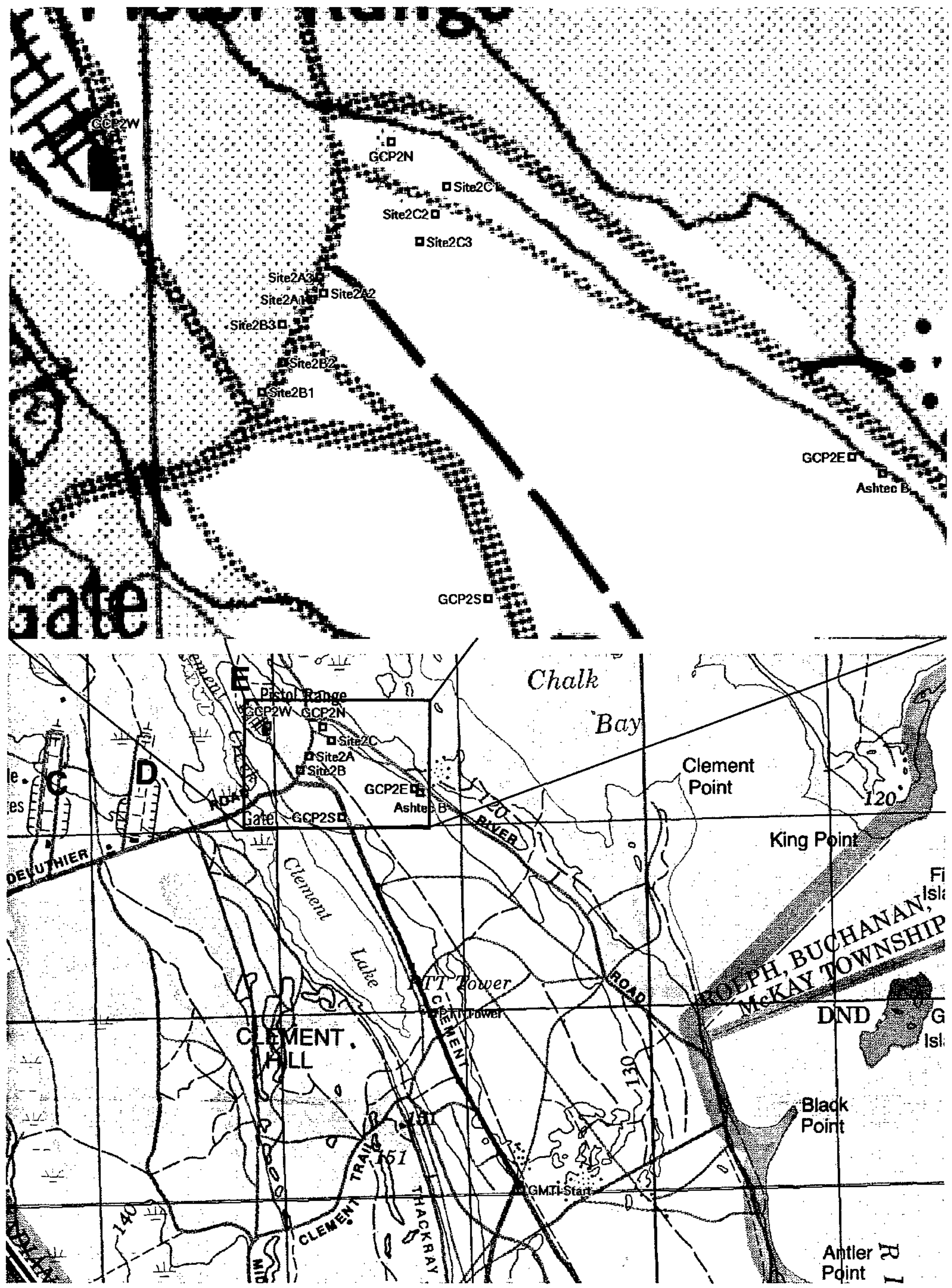

Figure 6. GPS locations of vehicles and GCPs at Site 2 including GMTI track (bottom) along Clement Lake Road.

Site 2 had three subsites: 2A was along the deciduous tree line, 2B was northwest of Deluthier Road and under the dense forest canopy, and 2C was in the open field. As with site 1A, there was a strip of grass a few meters wide between the gravelled surface of Deluthier Road and the tree line. The vehicles at 2A were backed up to the tree line, and the camouflage was deployed for optimal comparison against the dense canopy. For the DSSPM Observer Trial, the empty slot was the one adjacent to the northern-most slot.

Site 2B was located under the forest canopy, a few tens of metres back from Deluthier Road, north of the access road to Pistol Range E. As illustrated in Figure 4, the forest canopy was quite dense, and the vehicles were difficult to detect in airborne photos of the site. Site 2C was offset to the northeast from 2A and 2B to accommodate the DSSPM Observer Trial, which required an unobstructed view of site 2A from the southeast, along the western edge of the plain. As is illustrated in Figure 4, the ground around the vehicles at site 2C was mostly grass covered, and quite different from the exposed sand at site 1C.

Each of sites 2A, 2B and 2C had three vehicles of the same type, separated by at least 30 m, and oriented at 130°. LEOs were deployed at sites 2A and 2B, and COYs were deployed at site 2C. Figure 7 was copied from the Plan of Trial document, and illustrates (for the grid of subsite 2A/2B/2C versus position 1/2/3) which type of camouflage (if any) was used, and whether a thermal blanket was used. In this figure, CA1, CA2 and CA3 have the same meaning as in Figure 3. All vehicles were deployed stripped of their combat load. In Figure 8, ground photographs illustrate the deployed vehicles, for the same grid of subsite 2A/2B/2C versus position 1/2/3. In Figure 4, aerial photographs of sites 2A, 2B and 2C illustrate the immediate surroundings of the deployed vehicles, as described above.

a. Site 2 - MATTAWA

	1	2	3
1. Subsite B	LEO Bare	LEO CA2 CA3	LEO CA1
2. Subsite A.	COY CA1	COY CA2 CA3	COY CA2
3. Subsite C.	LEO Bare	LEO CA2	LEO CA1 CA3

Figure 7. Deployment of target vehicles at Site 2.

Note that in the Plan of Trial document [3], vehicles in sites 2A, 2B and 2C were given positions numbered 1, 2 and 3 from left to right. During the actual deployment, the relative orientation between subsites was not maintained. At sites 2A and 2B, positions were numbered 1 to 3 from south to north. This differs from site 2C, for which positions were numbered 1 to 3 from north to south.

In addition, Clement Lake Road, the main access road to Site 2 from the south, provided a relatively straight and level path on which a controlled moving vehicle could be introduced (i.e., the GMTI experiment of Section 4.5).

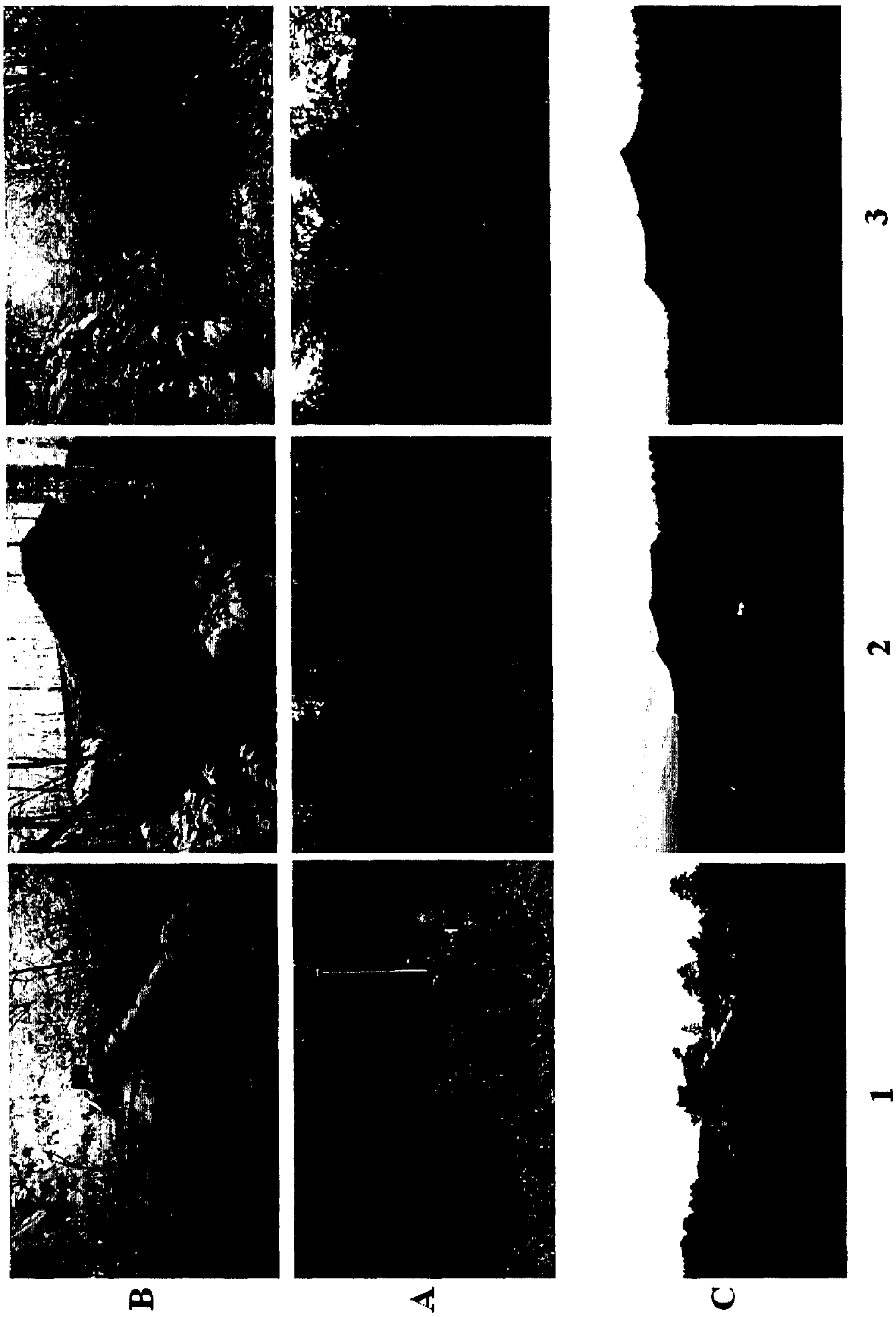

Figure 8. Vehicles deployed at Sites 2A, 2B and 2C in positions 1, 2 and 3.

2.3 Site 3: Shed

Site 3 was located at the observation hut (the "Shed") on the eastern edge of the DZ Anzio plain, approximately 0.75 km northwest of Totalize Road. The trial CP was established at the shed, and this was the organisational focal point of the trial activities. The shed was used as the administrative centre for the trial, serving as an office and meeting area, a lunchroom for personnel, and as a shelter for equipment storage and battery recharging. In addition to the CP, nine vehicles were deployed at Site 3 (described below), and a helicopter landing pad was set up in the field, about 50 m southwest of the shed. The positions for targets deployed at Site 3 are shown in Figure 9.

Due to the large number of people using this site and the variety of activities based at the CP and the parking lot, there was significant activity around Site 3. This included: (i) vehicles travelling up and down the east side of DZ Anzio plain, as they moved between Sites 1 and 3, (ii) a variable number of vehicles in the parking lot, (iii) the helicopter arriving at and departing from its landing site, and (iv) the loading of people into vehicles for the DSSPM Observer Trial.

Site 3 was also the location of the linear array of nine vehicles that were selected for use as confusor and training vehicles for the Assisted Target Recognition (ATR) experiment. These nine vehicles were all bare (neither camouflage netting nor thermal blankets were deployed), and they were separated by at least 30 m, and oriented at 130°. Starting closest to the shed and working out east to west, these vehicles were: MLVW 2.5-Ton cargo vehicle (MLVW), LSVW 1.5-Ton cargo vehicle (LSVW), Styer 10-Ton cargo vehicle (10T), ILTIS 0.25-Ton personnel vehicle (ILTIS), Grizzly armoured personnel carrier (G), LEO, COY, M109 self-propelled Howitzer (109), M113 armoured personnel carrier (113). In Figure 10, an aerial photograph illustrates the relative spacing between the vehicles and the CP, and the predominately grassy ground cover immediately surrounding the vehicles. In Figure 11, ground photographs are used to illustrate each vehicle. Note that there was small-scale local topography along the linear deployment of vehicles, and it was more pronounced than at Site 2C.

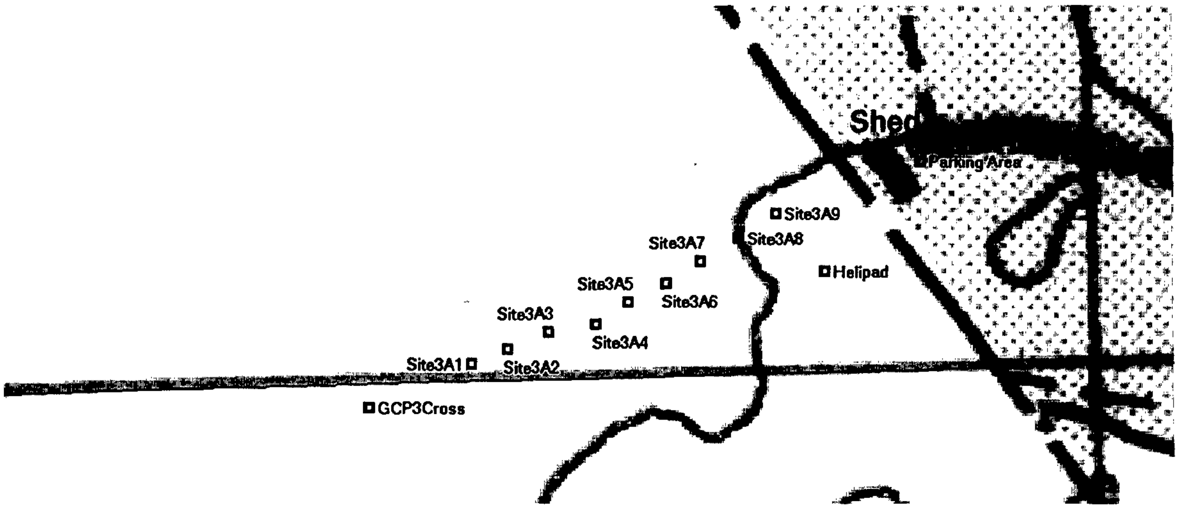

Figure 9. GPS locations of vehicles, Observation Hut ("Shed"), and parking lot at Site 3.

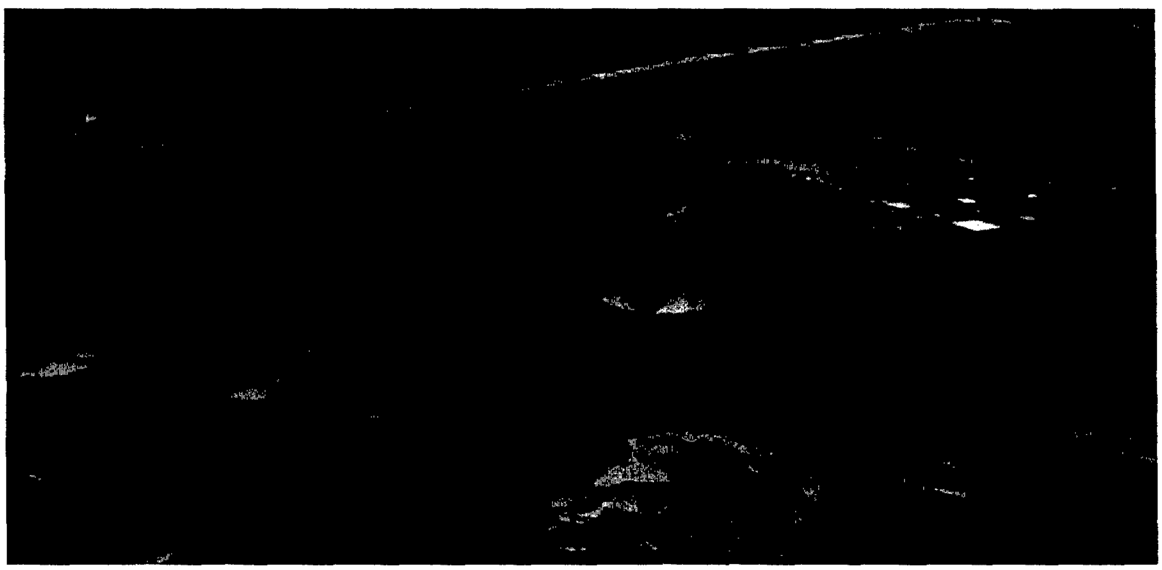

Figure 10. Overhead view of Site 3 in the deployed configuration, linearly outward from the shed.

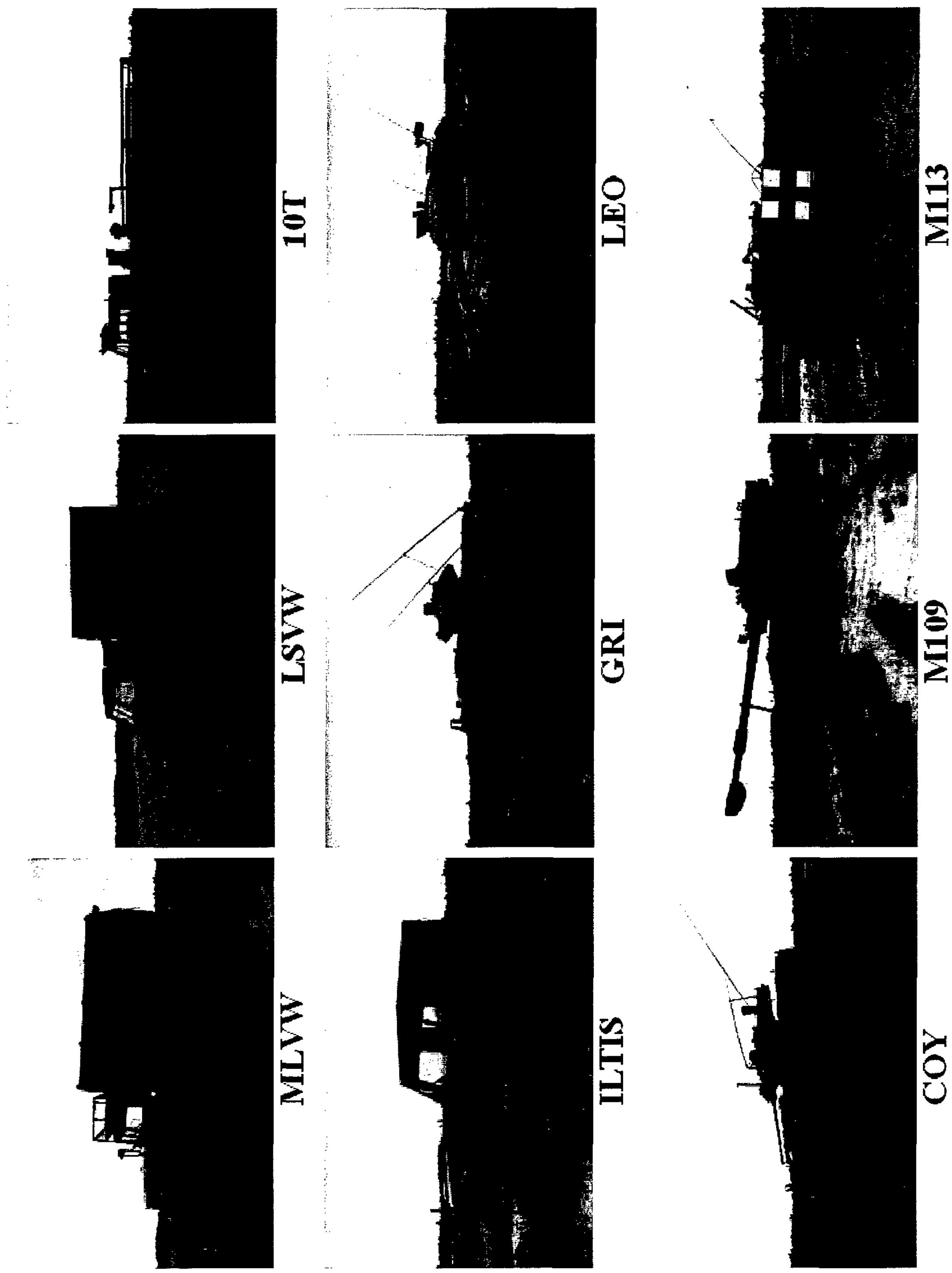

Figure 11. Vehicles deployed at Site 3 in positions 1 to 9. The MLVW was in position 9, and was closest to the shed.

3. Ground Control Points and Calibration Sites

In addition to the vehicle deployments at Sites 1, 2 and 3, three calibration sites were established during the trial: one for SAR experiments, and two for HSI experiments. These sites required relatively flat terrain without obscuration from forest canopy, but within the imaging path of the airborne sensors. For convenience, they were located relatively close to Site 3; however, they were placed sufficiently far from the vehicle deployment so as not to cause interference in the acquired imagery.

Also, corner reflectors (CRs) were deployed around Sites 1 and 2 and within Site 3, and a subset of these will appear as localized bright sources in most of the airborne SAR images. Accurate positions were measured for each of these, and they will be used as ground control points (GCPs) during analysis of the SAR imagery.

3.1 Corner Reflectors for SAR Imagery Ground Control Points

Since SAR imagery exists in the range versus cross-range plane, co-registration of imagery from different azimuthal and depression angles is not a trivial task. To aid in this process, it is customary to geo-locate GCPs around an area of interest. Ideally, these GCPs should act as point scatterers at ground level with high Target-to-Clutter Ratios (TCRs) and appear in every scene containing the region.

In practice, metallic CRs are used as GCPs since they perform as trihedral point scatterers. When deployed in a field or other clearing, a high TCR is easily achieved over a ±20° deviation from the boresight of the corner reflector, providing a fairly large tolerance to the incoming direction of the radar beam during imaging. For images that differ in angle by more than 20°, either the CR must be rotated, or an additional CR must be co-located and pointed in a complementary direction.

The existence of the Site 1 and Site 2 tree lines in this experiment set up natural azimuthal angles of interest. These were: the two directions perpendicular to the tree line, and the two directions parallel to the tree line. Since the two tree lines were not parallel, but would be imaged simultaneously, an average tree line was calculated to be 220° and the four azimuthal angles taken as 90° rotations from there: 220°, 310°, 40° and 130°.

Based upon these angles, the proposed deployment locations for GCPs at Sites 1, 2, and 3 were selected, and these are illustrated in Figure 12 (a) – (c). (Note that these positions may differ from the actual positions given in Section 3.) At Sites 1 and 2, expendable CRs (i.e., non-reorientable CRs) were deployed in pairs, where each pair of expendable CRs had an azimuthal separation of 180°. Expendable CRs in the north and south locations were pointed at 40° and 220°, while in the east and west locations they were pointed at 130° and 310°. In this configuration, every image taken from a primary azimuthal direction will have two GCPs visible: one in the near-range and on the right, the other far-range and on the left. This allows for good separation in both the range and cross-range dimensions. Site 3 differs from Sites 1

and 2, due to its proximity to the calibration field and the limitations on positioning equipment near the high-traffic area of the CP. As Figure 12 illustrates, a cross formation of four expendable CRs was proposed, with each expendable CR oriented toward one of the four primary azimuth directions.

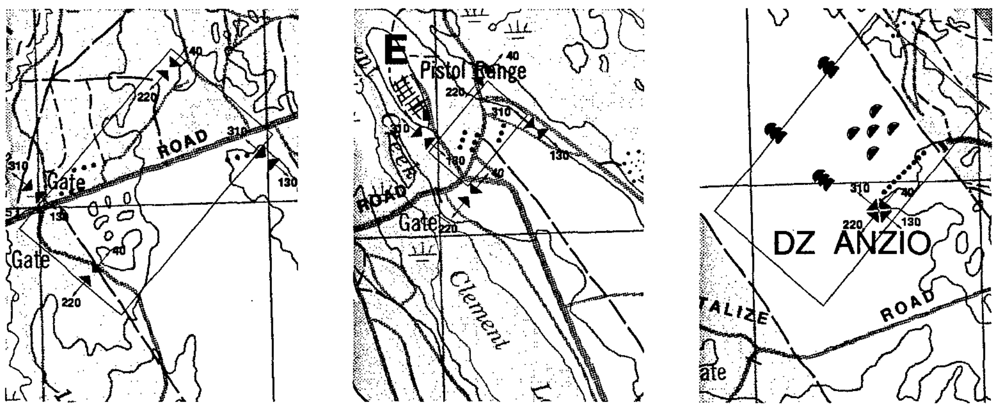

Figure 12. Proposed deployment locations for GCPs and SAR calibration equipment at (a) Site 1, (b) Site 2 and (c) Site 3 and Calibration Field. The blue boxes indicate the main azimuthal directions of data acquisition and give relative near-far/left-right perspective. The green disks are proposed vehicle locations. The bright red triangles are proposed expendable CR locations with boresight direction. The dark red triangles are proposed reorientable CR locations, and the stacked green half disks are proposed ARC locations.

For the LFSR trial, eight expendable CRs were deployed at Site 1, eight at Site 2, and four at Site 3, as planned. The actual locations for the 20 expendable CRs are illustrated in Figure 2, Figure 6 and Figure 9. For Sites 1 and 2, the deployed locations differed to varying degrees from the proposed locations given in Figure 12, primarily due to the presence of tree foliage. (A clear line of site to the airborne SAR sensors was required.) However, this actual deployment was close enough to the planned deployment, such that the main objectives were met. Accurate positions were measured for each expendable CR, so that they can be used as GCPs during analysis of the SAR imagery.

The azimuthal angles of the 20 expendable CRs remained unchanged throughout the LFSR trial. The elevation angle for a CR is the angle between its boresight and the ground, measured in degrees from the horizontal. The elevation angles of the expendable CRs were determined by performing a weighted averaging to locate the boresight that would accommodate as many lines as possible within the ±20° tolerance. They were also unchanged, remaining at their initial value throughout the trial. The values for these azimuth and elevation angles are provided in Table 7.

3.2 SAR Calibration Site

The SAR Calibration Site was located approximately 200 m north of the vehicle deployment at Site 3, and is illustrated in Figure 13. Here, five reorientable CRs and three polarimetric Active Radar Calibrators (ARCs) were deployed. All CRs have names assigned to them, and the ones used in this trial were DREO, DREV, DREP, DREA and Andromeda. Likewise, the three ARCs used in this trial were named Seraphina, Gemini and Power Hog.

The five reorientable CRs have well-defined RCS signatures; therefore, they are used to perform a radiometric calibration of the imagery for a scene containing them. These CRs were individually mounted on tripods with an adjustable elevation base, so that the direction of the boresight could be changed between flight lines. By pointing the boresight at the expected location of the radar, the CRs would be present in the SAR imagery, even for azimuthal angles that differ from the four primary angles (Section 3.1). In addition, these five CRs serve as additional GCPs in the airborne SAR imagery. For the June 4th acquisition of RADARSAT imagery (Table 5), one CR was removed (DREA) and replaced with a larger one (Medusa) suitable for the satellite acquisition. After the acquisition, the DREA CR was put back in place and left there for the remainder of the trial.

In addition to the radiometric calibration, a polarimetric calibration of the SAR data is required. The three ARCs deployed at the SAR Calibration Site respond only to C-band radar, so only the C-band imagery could be properly calibrated. Like the reorientable CRs, the orientation and elevation of the ARCs were matched to the parameters of each flight line. Note that the Gemini ARC was more difficult to align in orientation and elevation, and in some instances it was not used.

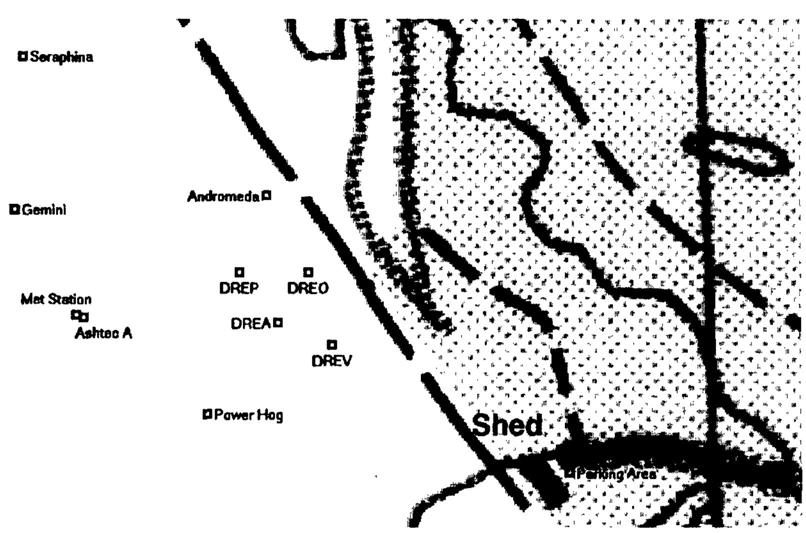

Figure 13. GPS locations of CRs and ARCs at the SAR Calibration Field.

In addition to the CRs and ARCs described above, a meteorological station and Ashtec differential GPS (dGPS) base station were deployed at this site. The meteorological station was an Aanderaa Instruments DataLogger 3600 with a 4-m aluminium mast. It recorded wind speed and direction, temperature and quantity of rainfall. The dGPS base station used was the Ashtech Z12. It was used with the GPS receiver on board the Convair 580 (CV-580) to derive accurate dGPS information required for processing of the SAR imagery. The positions of the meteorological station and dGPS base station are illustrated in Figure 13. A second Ashtech base station was deployed near Site 2, as illustrated in Figure 6.

3.3 Hyperspectral Calibration Site

The main HSI Calibration Site was located approximately 300 m south of the vehicle deployment at Site 3, and a second site was established near Totalize Road (Figure 1).

Within the main site there were 19 targets deployed, as illustrated in Figure 14 and Figure 15. There were five different types of material used for these targets, and for each material type there were four to seven targets, ranging in size from 12m x 12m down to 0.2m x 0.2m. The varying size of these targets in the HSI data will be used to test spectral unmixing (sub-pixel detection and recognition) algorithms. Spectral measurements of these calibration targets were made constantly throughout the periods that the airborne HSI sensor was acquiring data of the LFSR trial sites. These measurements will be used to provide a calibration for the HSI data, by providing a conversion between digital numbers and radiance.

In addition to the calibration targets, there were multiple targets deployed for two different HSI experiments. First, a bright target over a dark target was deployed for the adjacency effect experiment. The dark target was 11 m x 14 m, and the bright target was 3 m x 3 m. This experiment will evaluate the effect that adjacent pixels have on the spectrum of a small target. Second, four targets were deployed on the second site near Totalize Road for the bi-directional reflectance effect experiment, which will be used to evaluate the effects of an inclined surface on the HSI data. Each of these targets was 2.5 m x 2.5 m and they were inclined at angles of 0°, 10°, 20° and 40°.

Three types of portable ground-based sensors were used to support the airborne HSI acquisitions. These are the (1) GER-3700™ portable spectrometer, (2) the FieldSpecPro FR™ portable spectrometer, and (3) the LAI-2000 plant canopy analyser. The GER-3700™ was used to measure the radiance and reflectance spectra of the calibration targets, various surface types surrounding the targets (e.g. grass, sand, gravel roads), and the camouflage nets. Refer to Figure 16 for an illustration of the GER-3700™ recording the spectrum of soil and grass near a HSI calibration target. These spectra will be used to calibrate the signal, and build a spectral library that will help interpret the results of the HSI analysis. The FieldSpecPro FR™ was used to measure the solar irradiance during the overflights. The LAI-2000 plant canopy analyser was used to measure the percentage of the sky blocked by forest canopy above each of the vehicles at Sites 1A, 1B, 2A and 2B. The data acquired with the LAI-2000 will allow the derivation of total plant projected area (equivalent to leaf area index) and total biomass. It will indicate how much signal one would expect to detect through the forest canopy.

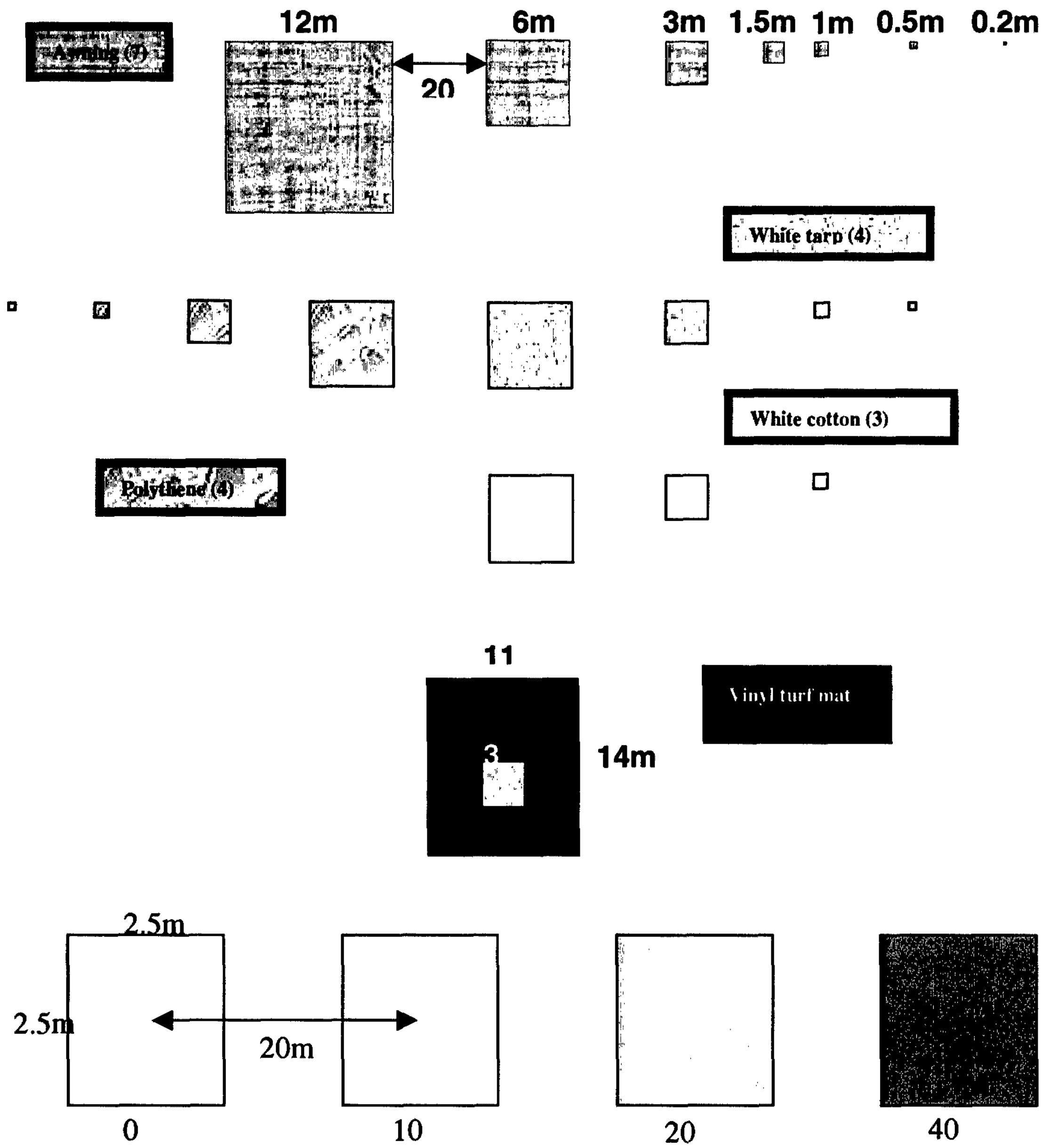

Figure 14. Layout of the HSI Calibration Sites, including targets for the spectral unmixing and bi-directional reflectance experiments.

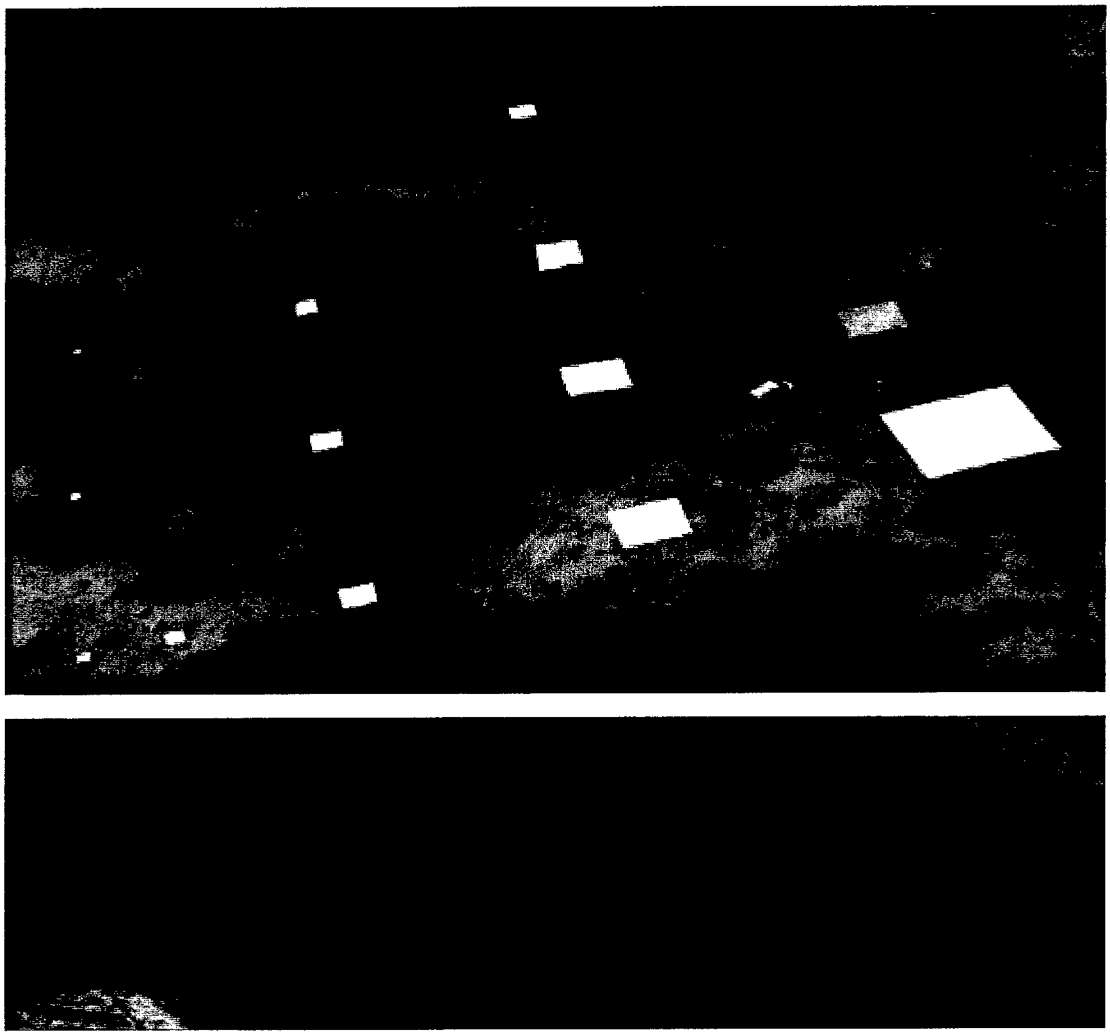

Figure 15. Air photograph taken during set up of the HSI Calibration Sites. The lower photograph shows targets used for the bi-directional reflectance experiment that were set up just north of Totalize Road.

Figure 16. The GER-3700 field spectrometer was used to acquire high-resolution spectra of targets of interest. It is shown here measuring grass-covered sand within the HSI Calibration Site.

4. DRDC Experiments

4.1 RCS Measurement

The LFSR trial was organised with the purpose of assessing the effectiveness of the trial camouflage screen (CA2). DSSPM performed part of this assessment using their Observer Trials and airborne multispectral imagery, by comparing the trial screen's pattern and colours against coniferous and deciduous forest canopy, and against the in-service netting.

DRDC Ottawa worked in collaboration with DSSPM to assess the effectiveness of the trial screen at radar frequencies. The CA2 screen is a camouflage system that works at radar frequencies in addition to VNIR and TIR wavelengths. Laboratory testing performed by the manufacturer[1] determined that the system results in a reduction in the average radar cross section (RCS) of several decibels (dB) at 9 GHz, 35 GHz, and at 94 GHz [1]. This is in contrast to the in-service camouflage netting, which has no effectiveness at radar frequencies.

For the RCS Measurement Experiment, only the six LEOs deployed at Sites 1C and 2C were considered. These LEOs were all in the open field, well away from extraneous and complicating factors that would be introduced by a variable forest canopy. (The Data Fusion Experiment described in Section 4.4 will investigate the detection of targets along the tree line and under the forest canopy.) Of the six LEOs, two were covered with the in-service nets, two had the CA2 trial screens combined with a thermal blanket, one had a thermal blanket only, and one was completely bare.

The three primary objectives of the RCS Measurement Experiment are to:

1. Determine the reduction in the *peak* RCS for LEOs camouflaged by the trial screen, when compared to LEOs that are effectively bare (i.e., those that are bare, and those that are covered with the in-service screen).

2. Determine the reduction in the *average* RCS for LEOs camouflaged by the trial screen, when compared to LEOs that are effectively bare.

3. Quantify the difficulty of detecting, in the SAR imagery, LEOs camouflaged with the trial screen, compared to other LEOs. The TCR, measured from the SAR imagery, will be used to assess this aspect.

The analysis for this experiment will consist of the following steps: manual selection of the six targets in the SAR imagery, extraction of small image chips from the larger data sets, and calculation of the RCS and TCR statistics. Note that these statistics will be calculated for all six targets on each image that was acquired. This includes 11 polarimetric C-band acquisitions and 13 partially-polarimetric X-band acquisitions spanning a range in azimuth and incidence

[1] In fact, the CA2 camouflage used in this trial was split into two varieties, with one variety resulting in a greater RCS reduction [1]. Whether or not the performance difference between these two screen types can be distinguished in our airborne SAR imagery will be investigated.

angles. Then, a statistical analysis will be performed to quantify the efficiency of the trial screen. With the six vehicles and the large number of images, the sample will be sufficiently large to assess the level of uncertainty in the RCS and TCR values, and derive results robust to changes in azimuth and incidence angles.

4.2 Camouflage Effects on ATR

Another measure of the performance of a SAR camouflage is its ability to reduce the likelihood of being recognised by ATR algorithms. DRDC Ottawa proposed to evaluate this kind of measure by including both a bare (uncamouflaged) training vehicle and confuser (non-target type) vehicles in the trial. These vehicles, located at Site 3, were imaged at identical orientations to those at Sites 1 and 2.

Using the known vehicle locations, standard-sized subimages of all the vehicles will be extracted from the SAR stripmap scenes. An ATR algorithm will be designed and implemented using AND Corporation's HNeT classifier, which has already been successfully employed to discriminate classes among a similar set of bare vehicles [5,6]. Training will be conducted on the Site 3 LEO, which corresponds to the vehicles under camouflage.

A baseline performance of the classifier can be established from the Receiver Operating Characteristic (ROC) curve generated on a test set composed of the bare LEOs in the open at Sites 1 and 2, along with the confuser vehicles at Site 3. The ROC curve parametrically plots the Percentage of Declared targets (P_d) versus the Percentage of False Alarms (P_{fa}) as a function of the detection threshold of the classifier [20]. All such ROC curves have (0,0) and (1,1) as endpoints. A random classifier generates the diagonal line between these points. The farther off diagonal the curve deviates, the better the classification performance on the data set. Any classifier achieving the ideal operating point at (0,1) is able to completely discriminate between target and non-target images in the data set being investigated.

Once a baseline ROC curve has been established for the LEOs without camouflage, the images of the bare vehicle will be swapped for the set under the in-service camouflage netting. Since these nets contain no Radio Frequency (RF) interference material, little change in the ROC curve is expected. Finally, the set of target vehicles will be swapped for those under the new camouflage, and we expect a measurable drop in the performance of the ATR algorithm [14].

The primary goal of the ATR Experiment is to measure the reduction in the ROC curve observed after applying a LEO classifier to SAR imagery containing camouflaged vehicles, and SAR imagery containing bare vehicles. The secondary goals of the ATR experiment are to determine the effects of tree line and canopy on automatic classification of vehicles in SAR imagery, and to determine the additional effects, if any, that camouflage has on the classification of vehicles along a tree line or under canopy.

To restrict target variability to primarily camouflage effects, precise measurements of the location and orientation of each vehicle are necessary. In particular, the geo-location should be known with an error less than half the minimum pixel size, which is 20 cm for this case. Similarly, the orientation should be known with an error such that the angular deviation over

the length of any vehicle is less than half the minimum pixel size. Since the greatest vehicle length is approximately 10 m, this translates to an angular tolerance of under 1.1° in orientation. In addition, CRs positioned at geo-located GCPs would enable scenes obtained from different depression and azimuthal angles of acquisition to be co-registered to minimise those variable effects.

To obtain this level of precision, the MCE was tasked to perform the measurements using RTK GPS methods. Accuracies of 2 cm geo-location and 0.1° orientation were offered as reasonably obtainable tolerances.

4.3 Hyperspectral Target Detection

In this study, DRDC Valcartier used a high spectral resolution SWIR imaging spectrometer, the SFSI-II, which records 240 bands at a sampling interval of 5 nm with a bandwidth of 13 nm in the 1200 – 2450 nm range. In mineral exploration, the SWIR region is well recognized for its ability to detect molecular absorption bands characteristic of various minerals [16]. Similarly, different man-made materials may exhibit diagnostic spectral features that enable their discrimination and identification. Laboratory spectrometric measurements on various target materials were performed prior to selecting a sensor for the LFSR experiments. It was found that while the colour of a material changed the shape of its reflectance spectrum in the VNIR, its shape remained constant in the SWIR, making it easier to identify. The SFSI-II sensor was selected for this experiment because of its high spectral resolution in the SWIR region, which gives it the potential of detecting target material that attempts to mimic the SWIR response of surrounding materials.

A *casi* VNIR sensor in multispectral mode was flown in conjunction with the SFSI-II sensor. The *casi* multi-spectral dataset will be used as part of the Data Fusion experiment, together with SAR and TIR imagery.

The main objectives of this study are: 1) to evaluate the performance of the two types of camouflage in the SWIR region, and 2) to develop processing methods towards Automatic Target Detection (ATD) from HSI data. Two ground experiments were designed to evaluate endmember selection and spectral unmixing algorithms [16,22], and the effects of bi-directional reflectance on the signal. These experiments will aid in developing a methodology for processing and analysing the HSI acquired over the camouflaged targets in Sites 1 and 2.

The Camouflage Experiment has the following objectives:

1. Comparison of GER-3700™ field reflectance spectra of the trial screen, in-service camouflage net and thermal blanket with vegetation spectra, to determine how well the spectrum of the trial screen matches with the forest canopy. This will consider how closely the spectra match, with respect to shape, amplitude, absorption features, and determine over what wavelength range they differ.

2. Determination of whether the trial screen makes it more difficult to detect targets using the airborne HSI data. This analysis will involve calibration of the SFSI-II data, and use of new algorithms to automatically select endmembers from the SFSI-

II data[22], followed by spectral unmixing of the HSI data. Then, anomaly detection algorithms will be used to generate anomaly maps for the sites of interest, which will be compared to the vehicle ground truthing.

The Spectral Unmixing Experiment consisted of deploying targets of various sizes, from 12 m x 12 m down to 0.2 m x 0.2 m, and materials (Figure 12). HSI data of these targets will be used to:

1. Test unmixing algorithms and estimate the sub-pixel detection limit for these various materials.
2. Evaluate which of the following two scenarios produce better results: (1) a lower signal level with higher spatial resolution – data was collected at 1.83 km (6000 ft), or (2) a higher signal level with a lower spatial resolution – data was collected at 2.90 km (9500 ft).
3. Evaluate the effect of varying illumination by comparing results acquired at three different times of the day.
4. Evaluate the adjacency effect of targets.

The Slanted Panel Experiment involved four 2.5 m x 2.5 m panels that were inclined from the ground at different angles (Section 3.3). These panels will be used to assess the bi-directional reflectance effects on the HSI data. The surfaces of the panels were painted with a commercial paint (Ferox green olive mat enamel #5870). The panels are illustrated in Figure 14 and Figure 15. The purpose of this experiment is to demonstrate how the apparent reflectance of a painted surface varies with view angle. A Bi-directional Reflectance Distribution Function (BRDF) for each material represents this property. Understanding this phenomenon is important to better interpret imagery of vehicles and other targets of interest that present inclined surfaces to the sensor. As well, it may be possible to develop target detection algorithms that are less sensitive to this phenomenon.

4.4 Data Fusion

The detection of land targets can be performed at some level on single sensor and/or single epoch data. However, this approach is limited because technologies can be utilised to deceive a specific sensor. For example, the probability of detecting targets with a SAR sensor can be reduced significantly by the proper use of RCS reducing camouflage. Similarly, camouflage with visible patterns that match with the natural surroundings[2] can reduce the probability of detecting targets using a panchromatic or multi-spectral Electro-Optical (EO) sensor. Land targets that are concealed by forest canopy pose additional problems, since traditional X- and C-band SAR and EO sensors do not penetrate this canopy, and therefore do not detect the targets. For this experiment, the ability to detect camouflaged and concealed land targets will

[2] The CA2 camouflage system used during the LFSR trial is an example that testifies to combine both the SAR and multi-spectral EO camouflaging.

be assessed using SAR and HSI data, together with advanced data fusion algorithms. It is expected that using these sensors with their differing phenomenology will raise the probability of detection of camouflaged and concealed land targets considerably.

HSI was chosen to complement SAR sensors for two reasons. First, HSI sensors measure the reflected light at hundreds of different wavelengths throughout the VNIR and SWIR regions of the spectrum. As a result, it is very difficult to design camouflage which is effective against HSI sensors, since it would be very difficult to match the spectral signatures to surrounding vegetation at all wavelengths. Second, exploitation of HSI data uses spectral unmixing algorithms that yield sub-pixel resolution [16]. Thus, a HSI sensor would have good chance of detecting a target that is partially visible through a forest canopy, provided that its spectral signature differs from its surroundings, and that the exposed target area makes up at least 5–10 percent of the total pixel area.

The detection of land targets is a critical component of the intelligence, surveillance and reconnaissance (ISR) work carried out by image analysts at the J2/GICI Canadian Forces Joint Imagery Centre (CFJIC). These analysts are faced with large volumes of multi-sensor imagery data, and they require a data fusion target detection system that they can use operationally. To meet these requirements, DRDC Ottawa and DRDC Valcartier have been collaborating to develop algorithms for the fusion of SAR and HSI data, using both pixel-level [10] and feature-level fusion architectures [9]. They have also been developing sensor-specific algorithms for detection of stationary targets in SAR and HSI data, including segmentation-based algorithms for SAR images and spectral unmixing algorithms for HSI data. One of the goals of this research is to improve detection of camouflaged and concealed targets.

The primary objectives of the Data Fusion Experiment are to use the SAR and HSI data from this LFSR trial to:

1. Validate new multi-sensor coregistration, data fusion and target detection algorithms using imagery data acquired under realistic deployment scenarios.

2. Determine whether the Probability of Detection (P_{det}) is higher using the fused SAR and HSI product, as compared to detections on either imagery when analysed individually.

3. Determine whether the False Alarm Rate (FAR) is lower for the fused SAR and HSI product, as compared to detections on either imagery when analysed individually.

4. Determine which of the SAR and HSI detection algorithms yield the highest P_{det} and lowest FAR for the difficult targets along the tree line and under the forest canopy.

5. Determine whether the CA2 trial camouflage screen results in a lower P_{det} for those targets along the tree line and under the forest canopy, as compared to targets covered by the in-service camouflage.

A secondary goal of the Data Fusion Experiment is to use multi-temporal RADARSAT-1 imagery and Coherent Change Detection (CCD) techniques to determine whether small changes occurring between 24-day repeat pass acquisitions can be detected. These changes could arise due to the presence of vehicles themselves, and possibly due to new tracks around Sites 1, 2 and 3 from deployment of the vehicles.

4.5 Polarimetric Interferometric SAR

With polarimetric SAR (PolSAR) sensors, spatially-coregistered images are acquired for the co-polarisation channels HH and VV, and the cross-polarisation channels, HV and VH. Since each polarisation has varying sensitivities to different surface characteristics and properties, PolSAR sensors improve the discrimination between and classification of features compared to single-channel SAR sensors [17]. With PolSAR imagery, it is possible to extract textural and spatial information for targets and clutter, such as orientation, structure/scatterer type, and surface material composition (density, moisture, etc.). With interferometric SAR (InSAR) techniques, multiple single-channel images from very similar perspectives (such as repeat-pass satellite acquisitions) are combined to yield the phase and coherence images, from which the surface vertical structure can be extracted [13].

The combination of these two methods is a relatively new area of study, which has not been fully explored. Preliminary research indicates that Pol-InSAR, the combination of PolSAR and InSAR, has enhanced spatial discrimination capabilities between target types and enhanced classification capabilities, by providing the capability to distinguish between targets and clutter at different elevations [2,18]. That is, it provides some 3-D effects in the sense that scatter types can be discerned as a function of elevation.

The initial difficulty arises from the repeat pass nature of the InSAR techniques. The key to successful multipass interferometry is to collect several data sets from almost the same perspective. To achieve the possibility of coherence with the CV-580 operating at C-band, the difference in elevation viewing angle between the various perspectives needs to be less than about 0.1°, which translates to a baseline of less than about 40 m.

The goal of the Pol-InSAR experiment is to determine if:

1. The required accuracy for the repeat pass acquisitions can be achieved.

2. The signal data acquired by the CV-580 SAR sensor can be processed to yield the 3D Pol-InSAR product.

3. The Pol-InSAR product can be used to detect targets along the tree line and under the forest canopy.

4. The detection of ground moving targets is possible – this is the GMTI experiment.

Towards this aim, the CV-580 was used to collect multipass C-band PolSAR imagery over LFSR trial Sites 1 and 2 on both 5 June and 8 June (Section 5.1). There were a total of five overpasses on 5 June, and nine on June 8. Out of all these combinations, a few resulted in

baselines of less than 40 m. One combination resulted in a baseline of less than 10 m, although not over the principle site of interest.

5. Airborne and Spaceborne Image Acquisition

During the LFSR trial, DRDC Ottawa and DRDC Valcartier acquired airborne SAR and HSI data and spaceborne SAR imagery. These acquisitions are described in the following three subsections. The guidelines for security classification of commercial imagery and spectral data acquired during this trial are provided in the Annexes.

5.1 Airborne SAR Data Collection

The PolSAR stripmap data set was acquired using the airborne C/X-SAR sensor developed by the Canada Centre for Remote Sensing (CCRS) and flown on Environment Canada's (EC) CV-580 airborne platform [7,11]. The PolSAR sensor was used in Nadir mode. At C-band, it had a slant-range (SR) resolution of 5.7 m and an azimuth (AZ) resolution of 0.85 m [8,11], and pixel sampling of 4.0 m and 0.43 m in SR and AZ, respectively. The corresponding ground range (GR) single look complex (SLC) imagery was generated using the PolGASP software at DRDC Ottawa [15]. The resulting imagery has 4096 pixels across the swath, which is approximately 19 km wide. A typical imaging geometry used during the LFSR trial is illustrated in Figure 17.

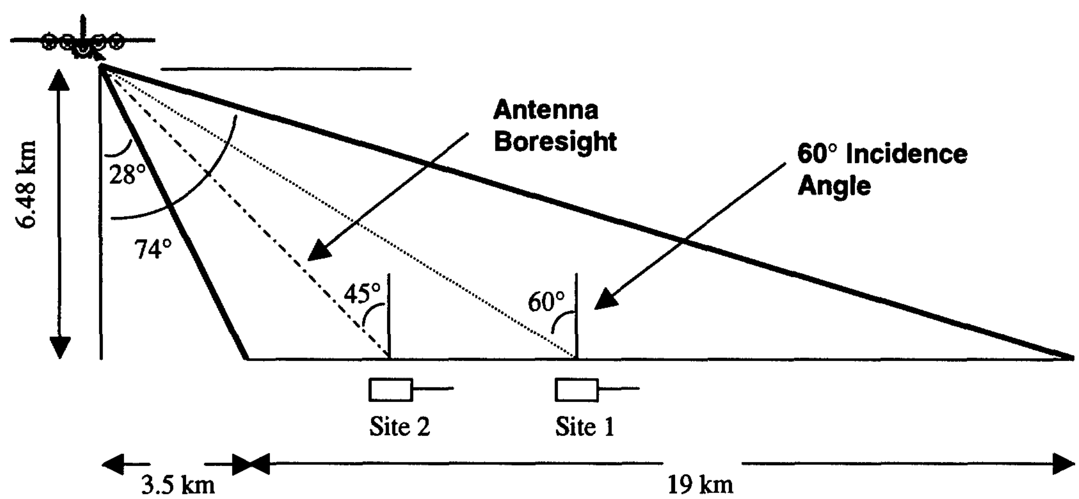

Figure 17. Geometry for the CV-580 SAR sensor for Line 7 on June 6, 2002, for which the aircraft flew on a 130° bearing. The right-looking SAR sensor was set for a 45° incidence angle at Site 2. In this configuration, Site 1 was imaged with an incidence angle of approximately 60°.

For this SLC imagery, the GR resolution r_g varies non-linearly across the swath, and is related to the SR resolution r_s by:

$$r_g / r_s = 1 / \sin\theta, \qquad (1)$$

where θ is the incidence angle [17]. For C-band, the GR resolution varies from r_g =12.1 m at the inner edge of the swath (θ=28°) to r_g=5.9 m at the outer edge of the swath (θ=74°). At an incidence angle of θ=60°, the GR resolution is 6.6m, while at θ=45°, the GR resolution is 8.1 m.

The C-band (5.30 GHz, 5.66 cm) PolSAR data is fully polarimetric, and it consists of four channels: HH, HV, VH and VV polarisations [7,11]. Here, the first letter represents the transmit polarisation, the second letter represents the receive polarisation, and H and V indicate horizontal and vertical polarisations. The X-band (9.25 GHz, 3.24 cm) SAR data were collected using the X+C Mode. In this mode, the data are partially polarimetric, and consist of two channels: HH and HV polarisations. The C-band imagery was calibrated using the ComplexCAL software [15] at DRDC Ottawa together with an analysis of returns from the ARCs and CRs deployed at the SAR Calibration Site. The X-band imagery was not calibrated since the equipment and software to calibrate it does not exist. However, it is still possible to analyse this X-band imagery in a relative manner, on a scene-to-scene basis.

For the LFSR trial, the number of SAR scenes that could be collected was limited by cost. Thus, the flight lines were selected to optimise the utility of the collection for the RCS and ATR Experiments. The parameters that vary between acquisitions include the *azimuth angle*, the *incidence angle*, and the *centre target.* Factors affecting their selection are described below.

The existence of the Site 1 and 2 tree lines set up natural azimuthal angles of interest: 220°, 310°, 40°, and 130° (refer to Section 3.1). Two additional azimuthal angles (175° and 265°) were selected to complement these, by rotating 45° in each direction from the primary direction of 220°. It must be noted here that these azimuthal angles represent the aircraft heading, but that the SAR sensor is right looking, perpendicular to this heading. Thus an azimuthal angle of 220° yields a view angle of 310°, which is face on for these targets deployed at a heading of 130°. Figure 18 illustrates the view angles for the right-looking SAR sensor with the six azimuthal angles listed above.

The incidence angle is illustrated in Figure 17. For an aircraft at a constant elevation above a flat earth, targets farther from the aircraft will have a larger incidence angle than targets closer to the aircraft. Previous SAR data collections have been acquired at various incidence angles. For example, the MSTAR data collection included incidence angles of 75°, 73°, 60° and 45° [13], and a DRDC Ottawa data collection in 1998 over CFB Petawawa included incidence angles of 60° and 45°. Hence, the choice was made to concentrate collections during the LFSR collections at incidence angles of 60° and 45°.

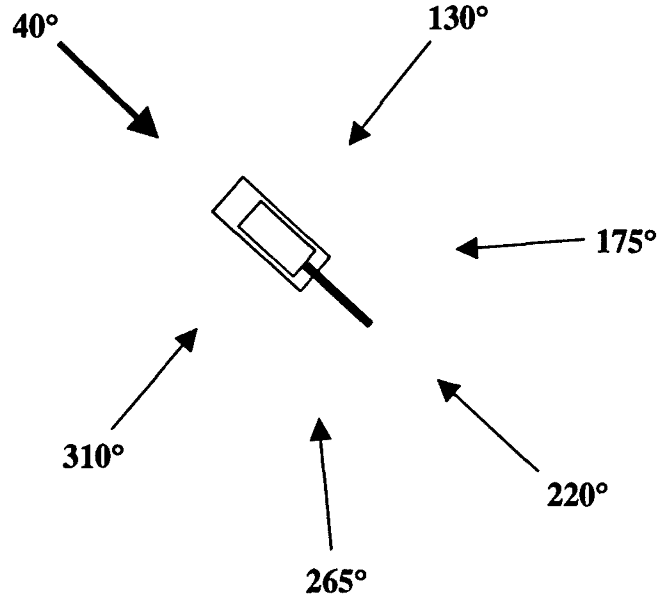

Figure 18. The arrows indicate the view angle for a right-looking SAR sensor flown at the azimuth angles indicated, with targets deployed at 130°.

The centre target is the third parameter, and it affects the image acquisition in the following manner. Objects that are located at the antenna boresight will have an incidence angle equal to that specified (either 60° or 45°). As illustrated in Figure 17, all other targets will have an incidence angle that varies in accordance with their proximity in the near or far range. By choosing different centre targets, matching incidence angles can be acquired for the three sites. Note that the aircraft altitude was not a variable parameter: it was fixed at approximately 6.4 km (21 000 ft).

5.1.1 RCS and ATR Experiments

The SAR acquisitions requested for the RCS Experiment are listed in the left side of Table 1. They were selected to provide C- and X-band imagery of the targets in the open at Sites 1C and 2C from incidence angles of 45° and 60° for nearly-face-on images, and at an incidence angle of 45° for side- and back-view images (to reduce the impact of the treeline on images of these targets). The acquisitions requested for the ATR Experiment are listed in the right side of Table 1. These lines were selected to ensure that vehicles deployed at Sites 1, 2 and 3 were imaged from azimuthal angles of 220°, 310°, 40° and 130° at incidence angles of both 60° and 45°. In this manner they complement the acquisitions requested for the RCS Experiment. For ease of acquisition by the CV-580 crew, these were regrouped to have all X+C band acquisitions on one day, and all fully polarimetric C-band acquisitions on another day. The regrouped and actual acquisitions are listed in Table 2.

Table 1. Proposed radar imagery acquisition requirements. (Top Left) Priority acquisitions for RCS measurements. (Right) Additional ATR acquisitions. (Bottom Left) UTM locations for Sites 1,2 and 3 plus two calculated midpoints for use as image centre targets.

Priority	Modes	Incidence Angle	Flight Bearing	Centre Target
Primary	Full C	60	220	B
	X+C	45	220	B
	X+C	60	220	B
	Full C	60	265	#1
	Full C	60	175	#2
Secondary	Full C	45	40	B
	X+C	45	310	1
	X+C	45	130	2
	X+C	45	40	B

Priority	Modes	Incidence Angle	Flight Bearing	Centre Target
Primary	Full C	60	220	#3
	X+C	45	220	#3
	X+C	60	220	#3
	X+C	45	40	#3
Secondary	Full C	60	265	#2
	Full C	60	175	A
	Full C	60	130	A
	Full C	60	310	A
	X+C	60	175	A
Tertiary	Full C	60	130	#2
	Full C	60	310	#2
	X+C	45	265	#1
	X+C	45	265	#3
	X+C	45	175	#1
	X+C	45	175	#3

Centre Target		Easting	Northing	Latitude	Longitude
#1	18T	0315200	5092100	45 N 57' 27.30"	77 W 23' 05.28"
#2	18T	0318100	5095300	45 N 59' 13.78"	77 W 20' 50.41"
#3	18T	0316800	5091000	45 N 56' 59.60"	77 W 21' 54.42"
A	18T	0316000	5091550	45 N 57' 10.27"	77 W 22' 27.39"
B	18T	0316700	5093800	45 N 58' 20.54"	77 W 21' 57.85"

Note: The flight bearing is given in degrees from true north, and the mean magnetic declination was -13.2 degrees.

Figure 19 and Figure 20 illustrate the CV-580 flight lines for June 6 and June 7, relative to CFB Petawawa. The flight lines are numbered in accordance with Table 2. For Figure 19, the black rectangle represents the region imaged during the green segment of flight line #6 (blue line) on June 6. The rectangle is split by the centre target line, from which the incidence angle of the image is measured. For this flight line, the centre target line is chosen to pass through Site 1 providing an incidence angle of 45°, while simultaneously imaging Site 2 at 60°. For Figure 20, the black rectangle represents the region imaged during the green segment of flight line #1 (blue line) on June 7. For this flight line, the centre target line is chosen to pass through both Sites 1 and 2 providing an incidence angle of 60°.

Table 2. *Flight line requirements and acquisitions according to flight profiles for X+C band collection (Jun 6) and fully Polarimetric C-band collection (Jun 7). Centre target locations provided in Lat/Long format.*

			Desired			Actual				
	Line	Modes	Incidence Angle	Flight Bearing	Centre Target	Incidence Angle	Flight Bearing	Altitude (ft. HAE)	Start time	Base filename
June 6	1	X+C	45	220	B	-	-	-	-	J6L1P1
	2	X+C	60	220	B	59.2	220.2	21 270	17:36:50	J6L2P3
	3	X+C	45	220	#3	42.4	220.2	21 270	17:58:30	J6L3P4
	4	X+C	60	220	#3	58.5	220.2	21 270	18:19:54	J6L4P5
	5	X+C	45	40	#3	44.9	40.1	21 260	18:32:09	J6L5P6
	6	X+C	45	310	1	43.4	309.9	21 280	19:17:13	J6L6P9
	7	X+C	45	130	2	-	-	-	-	J6L7P12
	8	X+C	45	40	B	59.9	40.0	21 270	19:32:20	J6L8P10
	9	X+C	60	175	A	59.0	175.0	21 260	19:44:53	J6L9P11
June 7	1	Full C	60	220	B	59.0	220.3	21 480	12:15:18	J7L1P1
	2	Full C	60	265	#1	59.0	265.2	21 480	12:33:52	J7L2P2
	3	Full C	60	175	#2	59.0	175.1	21 440	12:55:17	J7L3P3
	4	Full C	60	220	#3	58.3	220.2	21 490	13:13:36	J7L4P4
	5	Full C	45	40	B	43.6	40.0	21 490	13:29:09	J7L5P5
	6	Full C	60	265	#2	58.8	265.3	21 500	13:44:21	J7L6P6
	7	Full C	60	175	A	58.9	175.0	21 470	14:29:35	J7L7P8
	8	Full C	60	130	A	59.2	129.9	21 450	14:51:14	J7L8P9
	9	Full C	60	310	A	58.7	310.0	21 520	15:04:07	J7L9P10
	10	Full C	60	130	#2	58.4	130.0	21 460	15:17:55	J7L10P11
	11	Full C	60	310	#2	58.9	310.1	21 520	15:32:27	J7L11P12

Notes: 1) The flight bearing is given in degrees from true north, and the mean magnetic declination was -13.2 degrees. 2) Lines 1 and 7 acquired on June 6 could not be processed, due to an insufficient number of lines of noise data. 3) Line 9 acquired on June 6 suffered from poor motion compensation, and thus the targets are not focused. 4) Line 8 acquired on June 6 had an incidence angle of 60°, instead of the 45° angle that was requested. 5) Centre targets are defined in Table 1.

Orientation parameters for the ARCs and CRs deployed at the SAR Calibration Site (Section 3.2) are provided in Table 7 –Table 9 in the Annexes. Events which occurred during the acquisitions on June 6 and June 7 were logged. This is described further in Section 6.4.

5.1.2 Pol-InSAR Experiment

The polarimetric C-band images for the Pol-InSAR Experiment were acquired separately from the RCS and ATR Experiment acquisitions. As described in Section 4.5, the Pol-InSAR Experiment requires at least two acquisitions that are nearly repeat pass. That is, they must be acquired with the same azimuth angle, incidence angle and image centre point, with a tolerance of less than about 40 m. The azimuthal and incidence angles were chosen to be 220° and 60° respectively, with an image centre point located midway between Sites 1 and 2. (This is labelled as centre point B in of Table 1.) An attempt was made to acquire the Pol-InSAR data in the evening of June 5, but this was aborted midway through due to problems with the CV-580 aircraft. Only five acquisitions with the parameters described above were obtained. The Pol-InSAR Experiment was repeated during the morning of June 8, and nine acquisitions with the parameters described above were obtained. Events that occurred during the acquisitions on June 6 and June 7 were logged. This is described further in Section 6.4.

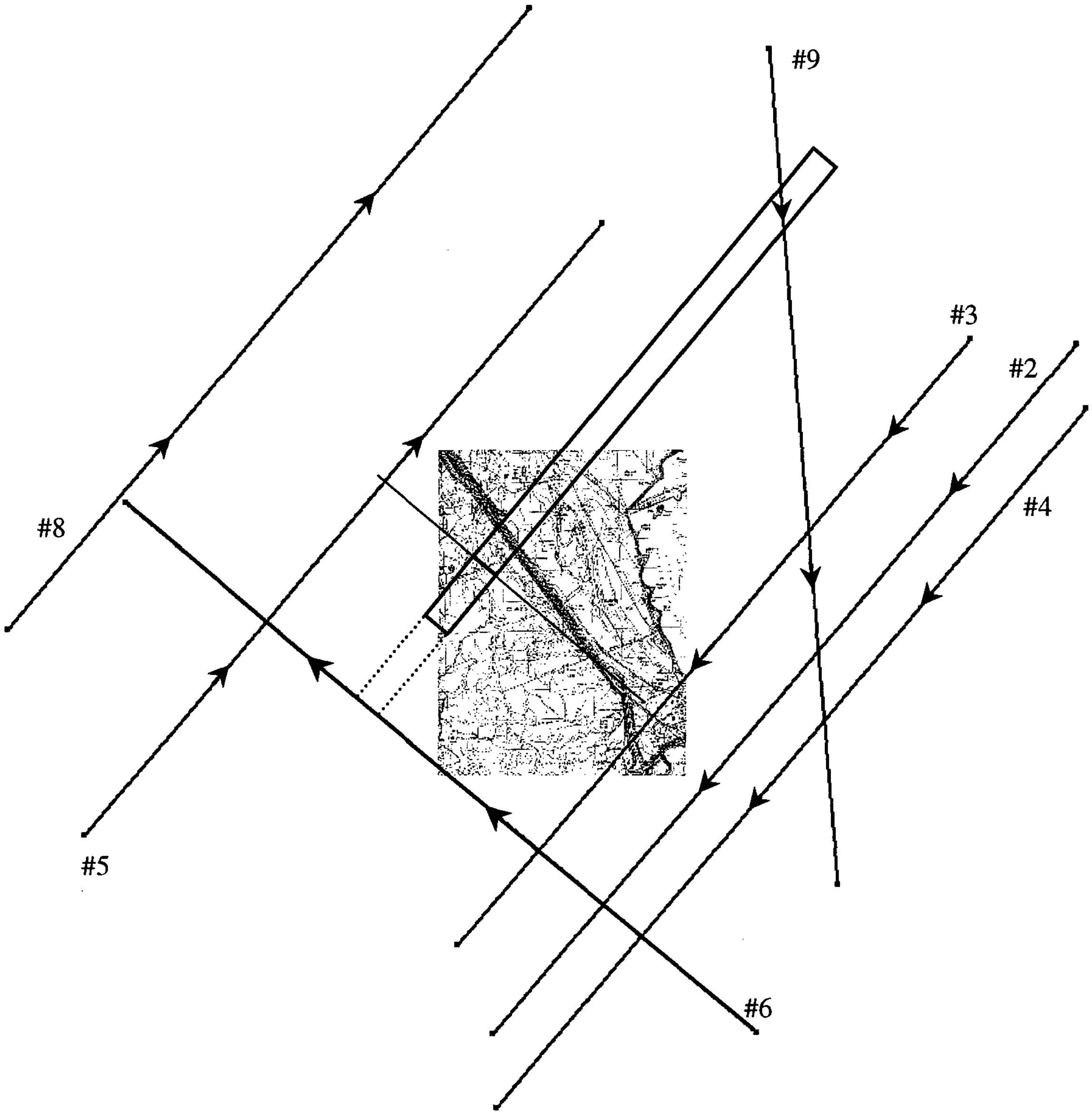

Figure 19: CV-580 flight lines for June 6 relative to CFB Petawawa. Lines are numbered in accordance with Table 2. Note that lines 1 and 7 could not be processed.

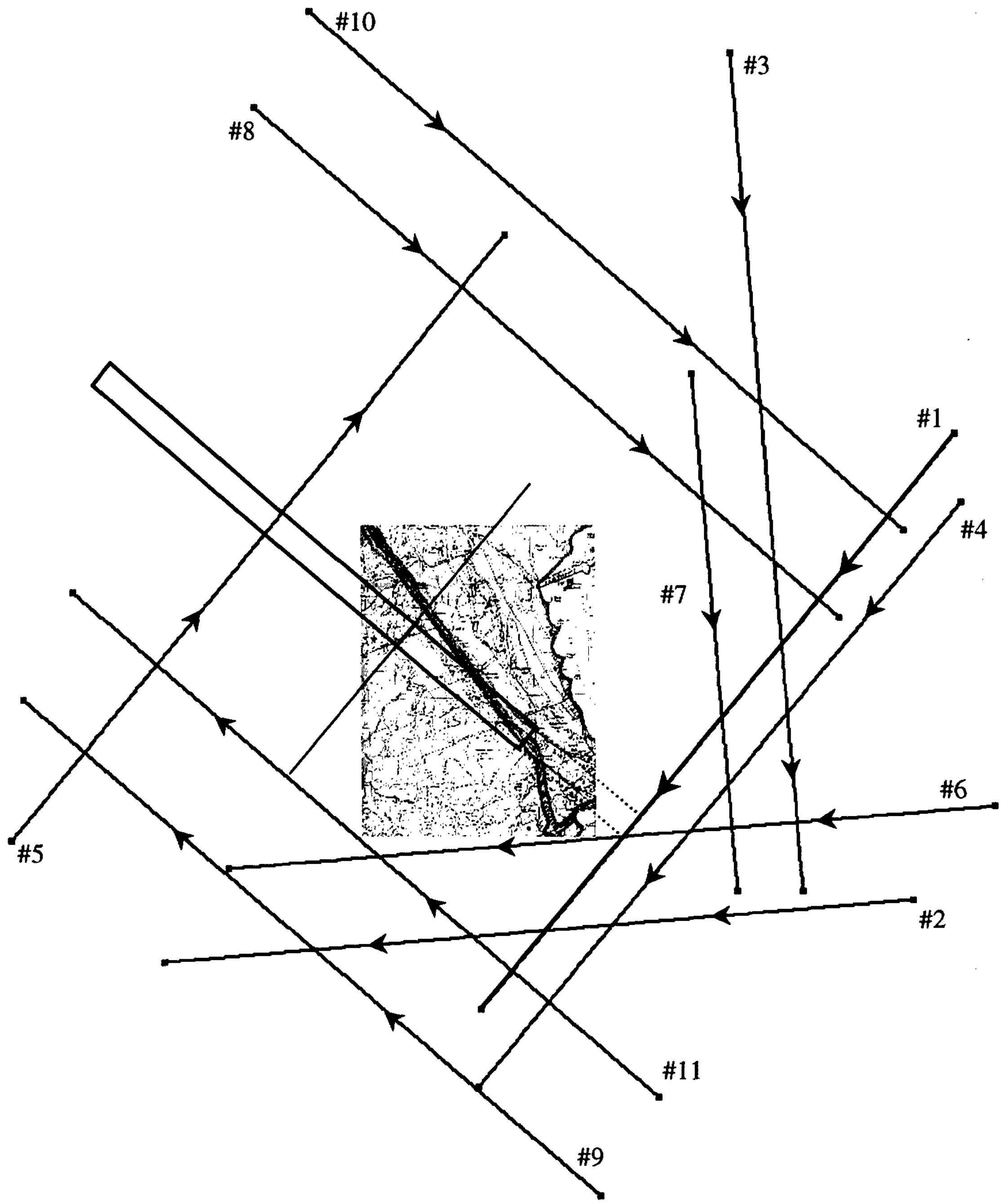

Figure 20: CV-580 flight lines for June 7 relative to CFB Petawawa. Lines are numbered in accordance with Table 2.

5.2 Airborne HSI Data Collection

The HSI sensors used in this experiment were the SWIR Full-Spectrum Imager (SFSI-II) and the Compact Airborne Spectrographic Imager (*casi*). Their specifications are listed in Table 3. The SFSI-II is owned by the CCRS, and both sensors are operated by Borstad and Associates. The aircraft used to carry the HSI equipment was a Bradley Airways' Beaver, which flew from their float plane base at Rapides-des-Joachims, PQ, located on the Ottawa River about 50 km northwest of Petawawa.

The image data were acquired along three flight lines (Figure 21) at 1.83 km (6000 ft) and 2.90 km (9500 ft) and at three different times (10:00, 13:00, 15:30). A set of images was first acquired in the morning of June 6 but due to the presence of haze and clouds the mission was aborted for the rest of the day. A complete set of images was acquired the following day on June 7. Table 4 lists the acquisition parameters and the sky condition of each flight line.

Table 3. *HSI Sensor Parameters.*

PARAMETER	SFSI-II	*casi*
Swath Width (px)	496	406
Spatial Resolution (m)	2 – 3	2 – 3
Spectral Range (nm)	1200 – 2400	400 – 1000
Number of Bands	240	4 – 9
Spectral Resolution (nm)	10	10

Note: The spatial resolution varies with altitude, from approximately 2 m at 1.83 km to 3 m at 2.90 km.

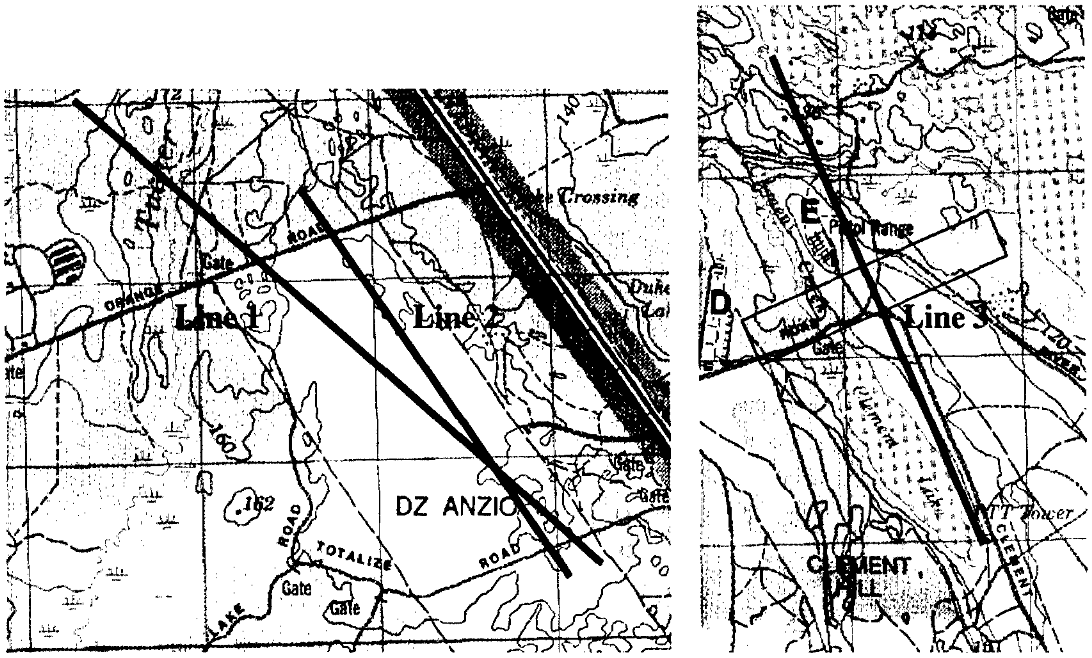

Figure 21: Approximate location of HSI lines 1, 2 and 3. The box centred on Line 3 illustrates the 1.5-km swath width for the SFSI-II sensor flown at 9500 ft.

Table 4. *Airborne HSI Acquisitions.*

DATE AND TIME	FLIGHT LINE	ALTITUDE (FEET)	HEADING (DEG FROM MAG NORTH)	SKY CONDITIONS
6 June 2002 10:24	1	9650	120	Haze, clouds overhead (cirrus, stratus)
6 June 2002 10:34	2	9600	145	
6 June 2002 10:43	3	9700	150	
6 June 2002 10:55	1	5000	120	
6 June 2002 11:03	2	5400	145	
6 June 2002 11:08	3	5500	320	
6 June 2002 11:17	X	5200	30	
7 June 2002 9:37	1	9500	155	Haze, some cirrus (not in sensor FOV)

7 June 2002 9:45	3	9500	345	
7 June 2002 9:53	2	9500	170	
7 June 2002 10:02	1	6500	135	
7 June 2002 10:07	2	6500	355	
7 June 2002 10:14	3	6500	170	
7 June 2002 10:25	2	6500	155	
7 June 2002 12:27	X	9400	120	Clear, low haze
7 June 2002 12:33	3	9500	330	
7 June 2002 12:41	1	9600	110	
7 June 2002 12:44	3	9700	320	
7 June 2002 12:51	2	9600	145	
7 June 2002 13:02	1	6000	110	
7 June 2002 13:06	3	6000	320	
7 June 2002 13:11	2	6000	120	
7 June 2002 15:22	1	9500	120	Clear, low haze
7 June 2002 15:26	3	9600	335	
7 June 2002 15:32	2	9600	145	
7 June 2002 15:41	1	5900	130	
7 June 2002 15:45	3	6100	335	
7 June 2002 15:51	2	6000	140	Haze, some cirrus (not in sensor FOV)

Notes: The locations for flight lines numbered 1, 2 and 3 are illustrated in Figure 21. An X indicates a flight line over water for calibration. All acquisitions include both *casi* and SFSI sensors.

5.3 Spaceborne SAR Data Collection

RADARSAT-1, launched in 1995, is Canada's first commercial radar remote sensing satellite [19]. It has a C-band (5.30 GHz, 5.66 cm) SAR that transmits and receives a single polarisation (HH). RADARSAT-1 is in a near polar orbit, with an inclination angle of 98.6 deg, an altitude of 798 km, and a repeat cycle of 24 days. The SAR sensor is right looking.

RADARSAT-1 has several beam modes, but the one of interest to this study is the Fine beam mode, which has a resolution of approximately 8m by 8m, and a swath width of 50 km. This is the highest resolution currently available[3] from commercial SAR sensors.

The RADARSAT-1 images were selected according to following priorities: all Fine beam mode acquisitions available during the LFSR trial, plus Fine beam mode acquisitions before and after, to be used for change detection analysis. These image requests and actual acquisitions are provided in Table 5.

[3] RADARSAT-2 is to be launched by Canada in 2004, and it will have an Ultra-Fine beam mode with ground resolution of 3 m x 3 m [23].

Table 5. RADARSAT-1 SAR Satellite Imagery Acquisitions.

DATE AND SCENE START TIME (GMT)	SCENE CENTRE COORDINATES	BEAM MODE (PRODUCT TYPE)	SCENE ID	RSI ORDER NUMBER
19 MAY 2002		FINE 5 NEAR DESCENDING (SLC)	NA	
21 MAY 2002 23:10:42.564	45°59′ N 77°21′ W	FINE 5 FAR ASCENDING (SLC)	C0023066	OGD_1477
29 MAY 2002 11:16:49.419	45°58′ N 77°21′ W	FINE 1 NEAR DESCENDING (SLC)	M0283846	OGD_1478
04 JUNE 2002 23:02:23.870	45°58′ N 77°22′ W	FINE 1 FAR ASCENDING (SLC)	M0285803	OGD_1479
05 JUNE 2002 11:12:39.516	45°58′ N 77°19′ W	FINE 3 NEAR DESCENDING (SLC)	M0285801	OGD_1480
12 JUNE 2002 11:08:27.045	45°58′ N 77°23′ W	FINE 5 NEAR DESCENDING (SLC)	M0286629	OGD_1481
12 JUNE 2002 11:08:28.327	45°58′ N 77°22′ W	FINE 5 NEAR DESCENDING (SGX)	C0023696	OGD_1894
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
21 JUNE 2002		FINE 3 FAR ASCENDING (SLC)	NA	
06 JULY 2002		FINE 5 NEAR DESCENDING (SLC)	NA	
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
30 JULY 2002		FINE 5 NEAR DESCENDING (SLC)	NA	
01 AUGUST 2002 23:10:36.860	45°57′ N 77°21′ W	FINE 5 FAR ASCENDING (SLC)	C0023576	OGD_1487

Notes: 1) Scenes are colour coded to indicate 24-day repeat-pass acquisitions. 2) NA in the SCENE ID column indicates that the scene was Not Acquired. This was due to RSI assigning a higher priority to another customer, or due to a satellite anomaly. 3) The two images from 12 June represent the same acquisition, but are different product types.

6. Ground Truthing

6.1 GPS Locations

Equipment positions were collected from various GPS sources, during deployment, photographing, and surveying. As described in the Introduction, the MCE section of J2/GICI performed a positional ground truthing of the deployed targets and calibration equipment using RTK GPS receivers. MCE was unable to meet the 2 cm position tolerance for vehicles at the tree line or under canopy, so this was relaxed to a 20 cm or 45 cm error when necessary. MCE were not able to collect data for vehicles at Site 2B, due to their inability to acquire a signal under the forest canopy. Bare vehicles in the open had all four corners measured so that position and orientation could be determined. Most other vehicles had only a single measurement taken and this was often at a measured offset to the vehicle position. These MCE measurements took place during the morning of Wed 5 June.

DRDC Ottawa also performed positional ground truthing using a combination of hand-held GPS and differential GPS receivers. This included positions, orientations and altitudes of all vehicles, expendable CRs, other objects of interest, and relevant landmarks (Table 10 – 17 in the Appendicies). In general, these are not as accurate as the RTK GPS measurements. Thus the definitive positions will be taken from the MCE data (where available), which are compiled in their ground truthing report [12].

6.2 Photography

MCE used a digital camera to photograph all target vehicles, GCPs and calibration equipment that they surveyed, as well as the GPS stations, weather station and prominent objects around the trial CP at DZ Anzio. These photos were consistently made north facing and are contained in MCE's ground truthing report [12]. Again, the vehicles under full canopy at Site 2B were not included in the MCE survey.

A more complete set of ground truth photos were acquired by DRDC Ottawa Photography Services during June 5 and 6. Approximately 600 digital photos were taken of the target vehicles, target environment and DRDC equipment with varying perspective and detail. Furthermore, approximately 75 photographs of the EC CV-580 and the radar equipment were acquired during the pre-flight testing phase.

Other members of DRDC Ottawa took photos of opportunity during the deployment and surveying of the equipment, as well as during the actual radar experiments. These were taken with both digital and conventional film cameras.

Aerial photography was conducted from a JetRanger helicopter on June 7. This aerial photography attempted to capture photos of the target sites from the same angles as the airborne sensors being flown, namely at 30° and 45° depression angles for the SAR sensors and 90° (straight down) for the HSI sensors. The primary bearings of 310° and 130° were used for these collections. The goal was to achieve fields of view of 100 m and 200 m, which

translated into flying altitudes of 76.4 m, 107 m, 153 m, 216 m and 305 m (250 ft, 350 ft, 500 ft, 710 ft and 1000 ft). This configuration is described further in the Annex to this report, entitled *Aerial Photography*. In addition to photos of the target sites, photos of the SAR and HSI Calibration Sites were acquired, as well as full site perspectives and prominent objects within the sites.

6.3 Soil Moisture

To assist in determining the clutter properties of the ground, soil moisture samples were taken using the Moisture Point™ soil moisture meter from Environmental Sensors Inc. Measurements were taken prior to the flights on June 5, 6 and 7. Measurements were not taken on June 8, since the rainfall during that day meant any soil moisture data would be invalid. For the June 5 flight, samples were taken from along the Site 3 line of vehicles, while they were taken from within the SAR Calibration Site for the remaining flights. These values are summarised in Table 6, while the full output of the soil moisture meter is provided in Table 17. Overall, the sandy soil drained well and consistently low moisture levels were recorded.

6.4 Events During Data Collection

Despite best efforts to keep the target sites static during data collection, some events were beyond the control of the trial organisers and scientists. Where possible, these events were recorded, with the primary responsibility for these observations resting with DRDC Ottawa Ground Control, the individual responsible for communications with the CV-580 aircraft.

Two events worth noting here are:

1. During the CV-580 flight in the evening of June 5, nine helicopters flew northwest up the west edge of the DZ Anzio plain, each disembarking a group of men and returning south down the plain. Two helicopters also remained hovering for extended periods of time at a location east of Site 1 and south of Site 2.

2. The DSSPM transports for the Observer Trial were moving up the western edge of the DZ Anzio plain on Thursday 6 June during the following times: 10:15–12:10, 12:30–13:15, 13:40–14:30, and 15:00–15:40.

Other targets of opportunity have been noted in the event logs (Table 18 –Table 21 in the Annexes).

Table 6. Soil Moisture Measurements (Summarised from Table 17).

Target	Soil Moisture	Average	Comments	Target	Soil Moisture	Average	Comments	Soil Moisture	Average	Comments
Date: 05-Jun-02				Date: 06-Jun-02				Date: 07-Jun-02		
M109 Left Front	15.8%			ARC Power Hog	11.9%			11.1%		
	14.7%	15.1%			11.8%			11.3%		
	14.9%				12.7%	11.9%		11.1%	11.2%	
					10.5%			11.2%		
					12.5%					
M109 Right Front	13.0%			GPS / Met Station	10.8%		2 different moisture zones	7.5%		Outlier # 1 not used again, 2 different moisture zones
	12.6%	12.8%			7.9%	8.2%		20.2%	19.5%	
	12.7%				10.6%	10.7%		18.7%		
					8.5%			10.1%	10.7%	
								11.9%		
								10.1%		
Grizzly Left Front	11.5%			ARC Gemini	10.3%			9.1%		
	11.9%	11.7%			9.1%	8.7%		8.9%	8.5%	
	11.6%				7.5%			9.1%		
					7.9%			6.7%		
Grizzly Right Front	10.1%			ARC Serafina	9.2%		Outlier #3 not used (may indicate 2 moisture zones)	7.5%		Outlier #3 not used (may indicate 2 moisture zones)
	9.9%	10.0%			7.2%			9.1%		
	9.9%				13.6%	7.6%		12.9%	8.2%	
					7.1%			7.9%		
					6.8%					
Box Truck Left Front	7.7%			Corner DREP	7.9%			9.4%		
	7.5%	7.6%			7.9%	7.7%	Outlier #4 not used	9.5%	9.2%	
	7.5%				7.4%			8.8%		
					10.1%			9.2%		
Box Truck Right Front	7.4%			Corner Andromeda	13.7%			16.7%		
	7.5%	7.5%			12.9%	10.9%	Possibly 2 moisture zones	14.7%	12.3%	Possibly 2 moisture zones
	7.5%				9.8%			10.2%		
					7.1%			7.5%		
				Corner DREO	10.5%			11.5%		
					15.3%	11.9%	Outliers #4, #5 not used	8.9%	10.3%	
					9.8%			10.5%		
					6.0%			10.1%		
					6.1%					
				Corner DREA	10.6%			15.1%		
					10.6%	10.5%	Outlier #3 not used	10.2%	12.8%	
					16.4%			12.5%		
					10.3%			13.5%		
				Corner DREV	15.1%			16.7%		
					13.5%	13.4%		19.2%	15.8%	Outlier #2 not used
					11.8%			15.4%		
					13.3%			15.4%		

7. References

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Annexes

Table 7. *Details of expendable CR deployment. Entries in black are desired values, while those in red are recorded measurements.*

Location	Direction to Aircraft	Corner Bore Azimuth (TN)	Corner Bore Azimuth (MN)	Corner Edge Alignment (Right to Left)		Corner Elevation (degrees from horizontal)		Easting (UTM)	Northing (UTM)
GCP 1N	NE	40	*53.1*	**143.1**	143	**-9.1**	-9.5	315871	5092397
GCP 1N	SW	220	*233.1*	**323.1**	323	**2.3**	2.1	315864	5092401
GCP 1E	SE	130	*143.1*	**233.1**	233	**0.4**	0.2	316021	5092235
GCP 1E	NW	310	*323.1*	**53.1**	53	**14.2**	14.4	316021	5092234
GCP 1S	NE	40	*53.1*	**143.1**	143	**-9.1**	-8.9	315013	5091939
GCP 1S	SW	220	*233.1*	**323.1**	323	**2.3**	2.5	315030	5091940
GCP 1W	SE	130	*143.1*	**233.1**	233	**0.4**	0.3	315026	5092129
GCP 1W	NW	310	*323.1*	**53.1**	53	**14.2**	14	315023	5092128
GCP 2N	NE	40	*53.1*	**143.1**	143	**2**	2.2	318265	5095551
GCP 2N	SW	220	*233.1*	**323.1**	323	**-9**	-8.9	318261	5095546
GCP 2E	SE	130	*143.1*	**233.1**	233	**0.5**	0.6	318757	5095201
GCP 2E	NW	310	*323.1*	**53.1**	53	**14**	13.9	318753	5095199
GCP 2S	NE	40	*53.1*	**143.1**	143	**2**	1.9	318359	5095057
GCP 2S	SW	220	*233.1*	**323.1**	323	**-9**	-9.2	318359	5095057
GCP 2W	SE	130	*143.1*	**233.1**	233	**0.5**	0.5	317966	5095564
GCP 2W	NW	310	*323.1*	**53.1**	53	**14**	14	317966	5095564
GCP 3Cross	NE	40	*53.1*	**143.1**	143	**7.8**	7.9	316428	5090980
GCP 3Cross	SW	220	*233.1*	**323.1**	323	**5.3**	5.4	316426	5090979
GCP 3Cross	SE	130	*143.1*	**233.1**	233	**-8.7**	-8.8	316427	5090979
GCP 3Cross	NW	310	*323.1*	**53.1**	53	**1.5**	1.6	316426	5090980

Table 8. *Deployment details for reorientable CRs. Entries in black are desired values, while those in red are recorded measurements. Red entries on yellow background indicate an unverified measurement. An "X" indicates azimuthal alignment achieved. "Unch" indicates the GCP was unchanged from the previous setting.*

					Andromeda CR4			DREO CR2			DREV CR1			DREA CR1			DREP CR3		
					Location (UTM)			**Location (UTM)**			**Location (UTM)**			**Location (UTM)**			**Location (UTM)**		
					0316601			0316636			0316654			0316611			0316569		
		All Locations			5091410			5091352			5091281			5091302			5091349		
	Line	Direction to Aircraft	Corner Bore Azimuth (MN)	Corner Edge Alignment (Right to Left)	Az.	Corner Elevation (degrees from horizontal)		Az.	Corner Elevation (degrees from horizontal)		Az.	Corner Elevation (degrees from horizontal)		Az.	Corner Elevation (degrees from horizontal)		Az.	Corner Elevation (degrees from horizontal)	
Wed	**1-9**	SE	*143.2*	**233.2**	X	**-3.6**	-3.6	X	**-3.6**	-3.6	X	**-3.6**	-3.6	X	**-3.6**	-3.6	X	**-3.6**	-3.6
Thu	**1**	SE	*143.2*	**233.2**	X	**17.7**	17.5	X	**18.1**	18.2	X	**18.5**	18.4	X	**18.2**	18.3	X	**17.8**	17.8
	2	SE	*143.1*	**233.1**	X	**-1.7**	-1.6	X	**-1.5**	-1.4	X	**-1.3**	-1.3	X	**-1.4**	-1.4	X	**-1.6**	-1.5
	3	SE	*143.2*	**233.2**	X	**8.5**	8.3	X	**8.8**	8.8	X	**9.0**	9.2	X	**8.8**	8.8	X	**8.5**	8.5
	4	SE	*142.9*	**232.9**	X	**-5.8**	-5.8	X	**-5.6**	-5.6	X	**-5.5**	-5.5	X	**-5.6**	-5.6	X	**-5.7**	-5.6
	5	NW	*323.2*	**53.2**	X	**10.3**	10.4	X	**10.0**	10.2	X	**9.7**	9.8	X	**9.9**	10.0	X	**10.2**	10.3
	6	SW	*232.9*	**322.9**	X	**7.6**	7.4	X	**7.7**	7.8	X	**7.9**	7.9	X	**7.9**	8.0	X	**7.9**	8.0
	6	*SW*	*232.9*	***322.9***	*X*	***7.6***	*7.7*	*X*	***7.7***	*7.6*	*X*	***7.9***	*8.0*	*X*	***7.9***	*8.0*	*X*	***7.9***	*7.8*
	7	NE	*53.3*	**143.3**	X	**-4.1**	-4.1	X	**-4.1**	-4.2	X	**-4.2**	-4.2	X	**-4.3**	-4.2	X	**-4.2**	-4.1
	8	NW	*322.9*	**52.9**	X	**3.6**	3.5	X	**3.4**	3.2	X	**3.2**	3.1	X	**3.3**	3.4	X	**3.6**	3.6
	7	*NE*	*53.3*	***143.3***	*X*	***-4.1***	*-4.0*	*X*	***-4.1***	*-4.2*	*X*	***-4.2***	*-4.2*	*X*	***-4.3***	*-4.2*	*X*	***-4.2***	*-4.3*
	9	E	*98.1*	**188.1**	X	**-3.9**	-3.8	X	**-3.8**	-3.9	X	**-3.7**	-3.8	X	**-3.8**	-3.9	X	**-3.9**	-3.8
Fri	**1**	SE	*143.2*	**233.2**	X	**-1.4**	-1.4	X	**-1.2**	-1.2	X	**-1.0**	-0.9	X	**-1.2**	-1.2	X	**-1.3**	-1.2
	2	S	*187.9*	**277.9**	X	**-3.5**	-3.5	X	**-3.3**	-3.2	X	**-3.1**	-3.0	X	**-3.2**	-3.2	X	**-3.3**	-3.2
	3	E	*97.8*	**187.8**	X	**-9.2**	-9.3	X	**-9.1**	-9.1	X	**-9.1**	-9.1	X	**-9.2**	-9.2	X	**-9.2**	-9.4
	4	SE	*142.8*	**232.8**	X	**-5.8**	-5.9	X	**-5.7**	-5.7	X	**-5.5**	-5.5	X	**-5.6**	-5.3	X	**-5.8**	-5.9
	5	NW	*322.9*	**52.9**	X	**4.0**	3.9	X	**3.8**	3.7	X	**3.5**	3.6	X	**3.7**	3.8	X	**3.9**	3.7
	6	S	*187.9*	**277.9**	X	**6.8**	6.8	X	**7.0**	7.0	X	**7.3**	7.2	X	**7.2**	7.1	X	**7.0**	6.8
	7	E	*98.1*	**188.1**	X	**-3.9**	-3.9	X	**-3.8**	-3.7	X	**-3.7**	-3.7	X	**-3.8**	-3.9	X	**-3.9**	-3.9
	7	*E*	*98.1*	***188.1***	-	***-3.9***	*Unch*	-	***-3.8***	*Unch*	*X*	***-3.7***	*Unch*	-	***-3.8***	*Unch*	-	***-3.9***	*Unch*
	8	NE	*52.9*	**142.9**	X	**-4.5**	-4.4	X	**-4.5**	-4.4	X	**-4.6**	-4.6	X	**-4.6**	-4.5	X	**-4.6**	-4.7
	9	SW	*232.9*	**322.9**	X	**-5.9**	-5.9	X	**-5.9**	-5.8	X	**-5.8**	-5.9	X	**-5.8**	-5.9	X	**-5.8**	-5.8
	10	NE	*52.6*	**142.6**	X	**-12.6**	-12.8	X	**-12.6**	-12.5	X	**-12.7**	-12.6	X	**-12.7**	-12.7	X	**-12.7**	-12.5
	11	SW	*233.3*	**323.3**	X	**7.4**	7.4	X	**7.5**	7.5	X	**7.7**	7.7	X	**7.7**	7.8	X	**7.7**	7.6
Sat	**1-9**	SE	*143.2*	**233.2**	X	**-3.6**	-3.5	X	**-3.6**	-3.5	X	**-3.6**	-3.6	X	**-3.6**	-3.5	X	**-3.6**	-3.7

Table 9. Deployment details for ARCs. Entries in black are desired values, while those in red are recorded measurements. Red entries on yellow background indicate an unverified measurement. An "X" indicates azimuthal alignment achieved. "Unch" indicates the ARC was unchanged from the previous setting.

		All Locations			Serafina				Power Hog				Gemini			
					Location (UTM) 0316376 5091559				Location (UTM) 0316534 5091226				Location (UTM) 0316367 5091411			
	Line	Direction to Aircraft	Corner Bore Azimuth (MN)	Corner Edge Alignment (Right to Left)	Az.	ARC Incidence (degrees from horizontal)	Left	Right	Az.	ARC Incidence (degrees from horizontal)	Left	Right	Az.	ARC Incidence (degrees from horizontal)	Left	Right
Wed	1-9	SE	143.2	233.2	X	58.3	58.3	58.3	X	58.3	58.3	58.3	X	58.3	58.3	58.3
Thu	1	SE	143.2	233.2	X	38.6	38.5	38.7	X	36.6	36.2	36.4	X	38.1	37.8	37.5
	2	SE	143.1	233.1	X	57.2	57.2	57.2	X	56.2	56.1	56.3	-		Unch	Unch
	3	SE	143.2	233.2	X	47.4	47.4	47.4	X	45.9	46.0	45.9	-		Unch	Unch
	4	SE	142.9	232.9	X	61.1	61.1	61.1	X	60.4	60.3	60.4	-		Unch	Unch
	5	NW	323.2	53.2	X	43.1	43.0	43.1	X	44.8	44.8	45.0	-		Unch	Unch
	6	SW	232.9	322.9	X	47.0	46.9	47.0	X	46.3	46.4	46.4	-		Unch	Unch
	6	*SW*	*232.9*	*322.9*	*X*	*47.0*	*46.9*	*47.0*	*X*	*46.3*	*46.4*	*46.4*	-		*Unch*	*Unch*
	7	NE	53.3	143.3	X	58.9	59.1	59.1	X	59.3	59.3	59.1	-		Unch	Unch
	8	NW	322.9	52.9	X	50.1	50.0	50.1	X	51.4	51.4	51.4	-		Unch	Unch
	7	*NE*	*53.3*	*143.3*	*X*	*58.9*	*58.9*	*59.1*	*X*	*59.3*	*59.3*	*59.1*	-		*Unch*	*Unch*
	9	E	98.1	188.1	X	59.1	59.2	59.1	X	58.8	58.8	58.6	-		Unch	Unch
Fri	1	SE	143.2	233.2	X	56.9	56.8	56.8	X	55.9	55.9	55.9	X	56.6	56.5	56.5
	2	S	187.9	277.9	X	58.6	58.5	58.7	X	57.7	57.7	57.7	-		Unch	Unch
	3	E	97.8	187.8	X	64.3	64.4	64.3	X	64.1	64.0	64.0	-		Unch	Unch
	4	SE	142.8	232.8	X	61.1	61.1	61.2	X	60.4	60.3	60.5	-		Unch	Unch
	5	NW	322.9	52.9	X	49.7	49.8	49.5	X	51.0	51.0	51.1	-		Unch	Unch
	6	S	187.9	277.9	X	48.7	48.6	48.8	X	47.2	47.2	47.2	-		Unch	Unch
	7	E	98.1	188.1	X	59.1	59.2	59.0	X	58.8	58.8	58.8	-		Unch	Unch
	7	*E*	*98.1*	*188.1*	-	*59.1*	*Unch*	*Unch*	-	*58.8*	*Unch*	*Unch*	-		*Unch*	*Unch*
	8	NE	52.9	142.9	X	59.3	59.3	59.4	X	59.6	59.6	59.6	-		Unch	Unch
	9	SW	232.9	322.9	313	60.6	60.6	60.7	X	60.2	60.2	60.2	-		Unch	Unch
	10	NE	52.6	142.6	X	67.4	67.5	67.5	X	67.6	67.7	67.6	-		Unch	Unch
	11	SW	233.3	323.3	X	47.2	47.1	47.1	X	46.5	46.4	46.6	-		Unch	Unch
Sat	1-9	SE	143.2	233.2	X	58.3	58.0	57.7	X	58.3	59.1	59.3	-	58.3	N/A	N/A

DRDC Ottawa GPS Data

Several sources for collecting GPS data were employed during the trial. DRDC Ottawa collected GPS data on various object locations using several models of Garmin handheld GPS receivers: two eTrex Vistas that provided location and barometric altitude data, one GPS-12 that provided date, time and location data, and a GPSMAP-76 that provided date, time, location and GPS altitude data. All handheld GPS data was collected with an error in the range ±6 – 8 m.

Table 10. *GPS data for locations at Site 1.*

LOCATION	GPS ID	DATE	TIME	UTM	EASTING	NORTHING	ALTITUDE	SOURCE
Site1A1	COY1A1			18T	315161	5092054	67.2 m	eTrex Vista 23210
	C101	2002-06-05	11:00:00	18T	315159	5092060		GPS-12 23145
Site1A2	COY1A2			18T	315183	5092064	51.8 m	eTrex Vista 23210
	C102	2002-06-05	11:26:00	18T	315177	5092068		GPS-12 23145
Site1A3	COY1A3			18T	315200	5092069	58.3 m	eTrex Vista 23210
	C103	2002-06-05	11:36:00	18T	315197	5092066		GPS-12 23145
Site1B1	COY1B1			18T	315237	5092133	70.8 m	eTrex Vista 23210
	C104	2002-06-05	12:12:00	18T	315230	5092141		GPS-12 23145
Site1B2	COY1B2			18T	315229	5092127	76.6 m	eTrex Vista 23210
	C105	2002-06-05	12:20:00	18T	315228	5092126		GPS-12 23145
Site1B3	COY1B3			18T	315201	5092127	80.6 m	eTrex Vista 23210
	C106	2002-06-05	12:29:00	18T	315205	5092120		GPS-12 23145
Site1C1	LEO1C1			18T	315918	5092162	142.4 m	eTrex Vista 23210
	04 Site1C1			18T	315914	5092158	141.4 m	eTrex Vista 23210
	C111	2002-06-05	13:22:00	18T	315920	5092170		GPS-12 23145
Site1C2	LEO1C2			18T	315883	5092156	144.8 m	eTrex Vista 23210
	C112	2002-06-05	13:32:00	18T	315888	5092160		GPS-12 23145
Site1C3	LEO1C3			18T	315860	5092142	145.8 m	eTrex Vista 23210
	05 Site1C3			18T	315876	5092133	145.3 m	eTrex Vista 23210
	C113	2002-06-05	13:32:00	18T	315856	5092148		GPS-12 23145
GCP1E	GCP1E NW			18T	316021	5092234	165.0 m	eTrex Vista 23210
	GCP1E SE			18T	316022	5092235	164.8 m	eTrex Vista 23210
	03 GCP1E			18T	316022	5092235	166.2 m	eTrex Vista 23210
	GCP (1E)			18T	316019	5092234	166.4 m	eTrex Vista 23210
	C114	2002-06-05	14:19:00	18T	316021	5092237		GPS-12 23145
GCP1N	GCP1N NE			18T	315871	5092397	164.3 m	eTrex Vista 23210
	GCP1N SW			18T	315864	5092401	163.1 m	eTrex Vista 23210
	C115	2002-06-05	14:39:00	18T	315866	5092401		GPS-12 23145
GCP1S	GCP1S NE			18T	315013	5091939	167.4 m	eTrex Vista 23210
	C108	2002-06-05	12:50:00	18T	315012	5091941		GPS-12 23145
	GCP1S SW			18T	315021	5091940	167.6 m	eTrex Vista 23210
	C107	2002-06-05	12:50:00	18T	315019	5091939		GPS-12 23145
GCP1W	GCP1W NW			18T	315024	5092128	164.5 m	eTrex Vista 23210
	GCP1W SE			18T	315026	5092129	165.2 m	eTrex Vista 23210
	C109	2002-06-05	13:01:00	18T	315021	5092133		GPS-12 23145

Table 11. *GPS data for locations at Site 2.*

LOCATION	GPS ID	DATE	TIME	UTM	EASTING	NORTHING	ALTITUDE	SOURCE
Site2A1	COY2A1			18T	318176	5095374	129.9 m	eTrex Vista 23210
	B105	2002-06-05	16:40:00	18T	318177	5095386		GPS-12 23145
Site2A2	COY2A2			18T	318181	5095387	130.1 m	eTrex Vista 23210
	B106	2002-06-05	16:50:00	18T	318182	5095392		GPS-12 23145
Site2A3	COY2A3			18T	318187	5095407	130.4 m	eTrex Vista 23210
	B107	2002-06-05	16:50:00	18T	318191	5095411		GPS-12 23145
Site2B1	LEO2B1			18T	318117	5095283	130.6 m	eTrex Vista 23210
	B102	2002-06-05	15:52:00	18T	318119	5095290		GPS-12 23145
Site2B2	LEO2B2			18T	318139	5095314	130.4 m	eTrex Vista 23210
	B103	2002-06-05	16:01:00	18T	318131	5095322		GPS-12 23145
Site2B3	LEO2B3			18T	318141	5095354	130.4 m	eTrex Vista 23210
	B104	2002-06-05	16:22:00	18T	318136	5095364		GPS-12 23145
Site2C1	B108	2002-06-05	17:03:00	18T	318326	5095501		GPS-12 23145
Site2C2	B109	2002-06-05	17:04:00	18T	318313	5095470		GPS-12 23145
Site2C3	B110	2002-06-05	17:09:00	18T	318300	5095439		GPS-12 23145
GCP2N	ST2 CRS NE	2002-06-06	15:14:00	18T	318261	5095546	134.5 m	GPSMAP-76 23118
	B112	2002-06-05	19:01:00	18T	318265	5095551		GPS-12 23145
GCP2E	ST2 CRS SE	2002-06-06	15:08:00	18T	318753	5095199	133.5 m	GPSMAP-76 23118
	B111	2002-06-05	18:31:00	18T	318757	5095201		GPS-12 23145
GCP2S	B115	2002-06-05	19:36:00	18T	318359	5095057		GPS-12 23145
GCP2W	B113	2002-06-05	19:15:00	18T	317966	5095564		GPS-12 23145
Martha	052 Martha	2002-06-04	17:19:00	18T	318755	5095189	128.7 m	GPSMAP-76 23118
	B101	2002-06-04	21:19:00	18T	318757	5095190		GPS-12 23145
Ashtec (Site 2)	053 Ash 23134	2002-06-05	11:22:00	18T	318789	5095179	132.1 m	GPSMAP-76 23118
Site2Photo	B114	2002-06-05	19:29:00	18T	318257	5095223		GPS-12 23145

Table 12. *GPS data for locations at Site 3.*

LOCATION	GPS ID	DATE	TIME	UTM	EASTING	NORTHING	ALTITUDE	SOURCE
M113	M113 3A1			18T	316510	5091016	164.8 m	eTrex Vista 23210
	APC 35026	2002-06-06	11:42:00	18T	316509	5091014	161.6 m	GPSMAP-76 23118
	A109	2002-06-04	18:20:00	18T	316510	5091014		GPS-12 23145
M109	M109 3A2			18T	316542	5091029	166.2 m	eTrex Vista 23210
	HOZ 34825	2002-06-06	11:45:00	18T	316537	5091026	163.3 m	GPSMAP-76 23118
	A108	2002-06-04	18:00:00	18T	316540	5091027		GPS-12 23145
Coyote	COY3A3			18T	316574	5091038	164.8 m	eTrex Vista 23210
	COY 31821	2002-06-06	11:47:00	18T	316570	5091037	162.1 m	GPSMAP-76 23118
	A107	2002-06-04	17:49:00	18T	316572	5091036		GPS-12 23145
Leopard	LEO3A4			18T	316613	5091044	165.0 m	eTrex Vista 23210
	LEP 85111	2002-06-06	11:49:00	18T	316611	5091043	161.9 m	GPS-12 23145
	A106	2002-06-04	17:29:00	18T	316610	5091042		GPS-12 23145
Grizzly	GRI3A5			18T	316637	5091059	165.0 m	eTrex Vista 23210
	GRZ 44530	2002-06-06	11:52:00	18T	316635	5091059	161.4 m	GPS-12 23145
	A105	2002-06-04	15:57:00	18T	316635	5091058		GPS-12 23145
Iltis	ILT3A6			18T	316666	5091073	164.0 m	eTrex Vista 23210
	ILS 87555	2002-06-06	11:54:00	18T	316664	5091072	161.1 m	GPSMAP-76 23118
	A104	2002-06-04	15:49:00	18T	316664	5091071		GPS-12 23145
HLVW	HLV3A7			18T	316697	5091089	165.0 m	eTrex Vista 23210
	1 (HLVW)	2002-06-04	15:48:00	18T	316690	5091097		GPS-12 23145
	EYR 92561	2002-06-06	11:56:00	18T	316695	5091089	161.6 m	GPSMAP-76 23118
	A103	2002-06-04	15:40:00	18T	316694	5091094		GPS-12 23145
LSVW	LLV3A8			18T	316724	5091106	166.4 m	eTrex Vista 23210
	LHT 97265	2002-06-06	11:59:00	18T	316722	5091105	162.3 m	GPSMAP-76 23118
	54 (LSVW)	2002-06-06	11:59:00	18T	316723	5091106	158.3 m	GPSMAP-76 23118
	A102	2002-06-04	15:31:00	18T	316721	5091110		GPS-12 23145
MLVW	MLV3A9			18T	316757	5091120	166.9 m	eTrex Vista 23210
	DUC 58483	2002-06-06	12:01:00	18T	316754	5091122	162.8 m	GPSMAP-76 23118
	A101	2002-06-04	15:12:00	18T	316754	5091122		GPS-12 23145
GCP3Cross	GCP3 NE			18T	316428	5090980	173.9 m	eTrex Vista 23210
	GCP3 NW			18T	316426	5090980	170.8 m	eTrex Vista 23210
	GCP3 SE			18T	316427	5090979	172.4 m	eTrex Vista 23210
	GCP3 SW			18T	316426	5090979	171.7 m	eTrex Vista 23210
	SITE3 4CRS	2002-06-06	11:39:00	18T	316425	5090981	165.7 m	GPSMAP-76 23118
	DSP S3 P			18T	316426	5090983	167.9 m	eTrex Vista 23209
	A119	2002-06-05	21:35:00	18T	316430	5090982		GPS-12 23145
Helipad	11 Helipad			18T	316788	5091078	73.4 m	eTrex Vista 23210
	Helicopter Cross	2002-06-07	16:00:00	18T	316769	5091054		eTrex Vista

Table 13. GPS data for locations at Radar Calibration Site.

LOCATION	GPS ID	DATE	TIME	UTM	EASTING	NORTHING	ALTITUDE	SOURCE
Met Stn	MET STN P			18T	316426	5091314	164.3 m	eTrex Vista 23209
	MET	2002-06-06	11:13:00	18T	316421	5091317	162.6 m	GPSMAP-76 23118
	47 (MET)	2002-06-04	14:36:00	18T	316423	5091320	164.8 m	GPSMAP-76 23118
	RAIN	2002-06-06	11:09:00	18T	316422	5091313	162.6 m	GPSMAP-76 23118
	48 (RAIN)	2002-06-04	14:38:00	18T	316424	5091315	165.0 m	GPSMAP-76 23118
Ashtec (Cal)	ASH 23133	2002-06-06	11:07:00	18T	316426	5091314	162.6 m	GPSMAP-76 23118
	49 (ASHTEC)	2002-06-04	14:41:00	18T	316428	5091316	164.5 m	GPSMAP-76 23118
	A115	2002-06-05	21:07:00	18T	316424	5091318		GPS-12 23145
Power Hog	40 (Power Hog)	2002-06-04	11:09:00	18T	316533	5091226	144.8 m	GPSMAP-76 23118
	ARC 2542 P			18T	316534	5091226	163.1 m	eTrex Vista 23209
	ARC 2542	2002-06-06	11:34:00	18T	316538	5091221	161.6 m	GPSMAP-76 23118
	A118	2002-06-05	21:24:00	18T	316538	5091224		GPS-12 23145
Gemini	41 (Gemini)	2002-06-04	11:15:00	18T	316365	5091414	165.2 m	GPSMAP-76 23118
	GEMINI P			18T	316367	5091411	166.0 m	eTrex Vista 23209
	ARC GEMIMI	2002-06-06	11:23:00	18T	316366	5091413	162.3 m	GPSMAP-76 23118
	A116	2002-06-05	21:13:00	18T	316369	5091413		GPS-12 23145
Seraphina	42 (Seraphina)	2002-06-04	11:18:00	18T	316380	5091555	164.0 m	GPSMAP-76 23118
	ARC 2756 P			18T	316376	5091559	165.5 m	eTrex Vista 23209
	ARC 2756	2002-06-06	11:27:00	18T	316379	5091553	163.5 m	GPSMAP-76 23118
	A117	2002-06-05	21:18:00	18T	316384	5091554		GPS-12 23145
DREV	43 (DREV)	2002-06-04	11:27:00	18T	316653	5091284	162.3 m	GPSMAP-76 23118
	75M CR1 P			18T	316654	5091281	162.1 m	eTrex Vista 23209
	DREV 75	2002-06-06	10:47:00	18T	316650	5091285	154.7 m	GPSMAP-76 23118
	A110	2002-06-05	20:38:00	18T	316655	5091284		GPS-12 23145
DREO	44 (DREO)	2002-06-04	11:32:00	18T	316635	5091352	159.9 m	GPSMAP-76 23118
	75M CR2 P			18T	316636	5091352	161.9 m	eTrex Vista 23209
	DREO 75	2002-06-06	11:03:00	18T	316633	5091349	160.9 m	GPSMAP-76 23118
	A112	2002-06-05	20:47:00	18T	316638	5091354		GPS-12 23145
DREA	45 (DREA)	2002-06-04	11:35:00	18T	316605	5091302	160.9 m	GPSMAP-76 23118
	100M CR1 P			18T	316611	5091302	162.6 m	eTrex Vista 23209
	DREA 75 (1-m)	2002-06-06	10:52:00	18T	316605	5091302	162.1 m	GPSMAP-76 23118
	A111	2002-06-05	20:44:00	18T	316610	5091307		GPS-12 23145
DREP	46 (DREP)	2002-06-04	11:39:00	18T	316569	5091349	161.1 m	GPSMAP-76 23118
	75M CR3 P			18T	316570	5091349	164.0 m	eTrex Vista 23209
	DREP 75 UL	2002-06-06	10:55:00	18T	316569	5091348	161.9 m	GPSMAP-76 23118
	A114	2002-06-05	21:28:00	18T	316572	5091350		GPS-12 23145
Andromeda	75M CR4 P			18T	316600	5091418	165.2 m	eTrex Vista 23209
	ANDROMED60	2002-06-06	10:58:00	18T	316597	5091418	164.3 m	GPSMAP-76 23118
	A113	2002-06-05	20:51:00	18T	316601	5091422		GPS-12 23145
Blue 4x4 (June 7)	Blue Truck (125 facing)	2002-06-07	16:00:00	18T	316507	5091590		eTrex Vista
Trucks (June 7)	Red Truck/DND Truck	2002-06-07	16:00:00	18T	316735	5091289		eTrex Vista

Table 14. GPS data for other locations.

LOCATION	GPS ID	DATE	TIME	UTM	EASTING	NORTHING	ALTITUDE	SOURCE
GMTI Start	63 (GMTI Start)	2002-06-08	08:24:00	18T	319275	5093020	133.3 m	GPSMAP-76 23118
	B200	2002-06-05	23:29:00	18T	319271	5093018		GPS-12 23145
Paquette	PAQ RD			18T	320541	5085247	51.3 m	eTrex Vista 23209
Orange @ Tucker	055 Orange @ Tucker	2002-06-06	12:53:00	18T	315030	5091998	162.6 m	GPSMAP-76 23118
	C110	2002-06-05	13:06:00	18T	315029	5092000		GPS-12 23145
Orange @ Messer	056 Orange @ Messer	2002-06-06	12:59:00	18T	316631	5092471	160.4 m	GPSMAP-76 23118
Messer @ Veritable	057 Messer @ Veritable	2002-06-06	13:09:00	18T	319010	5089039	165.7 m	GPSMAP-76 23118
Brindle @ Middle	058 Brindle @ Middle	2002-06-06	13:29:00	18T	320049	5089413	167.9 m	GPSMAP-76 23118
Air Field @ X	059 Air Field @ X	2002-06-06	13:40:00	18T	320634	5087671	152.5 m	GPSMAP-76 23118
Deluthier @ Middle	060 Deluthier @ Middle	2002-06-06	13:55:00	18T	317043	5094851	151.1 m	GPSMAP-76 23118
Waito @ River Rd	062 Waito @ River Rd	2002-06-06	14:26:00	18T	320390	5093357	121.0 m	GPSMAP-76 23118
PTT Tower	PTT Tower (Offset)	2002-06-08	09:40:00	18T	318823	5093989	93.0 m	Trimble 21616

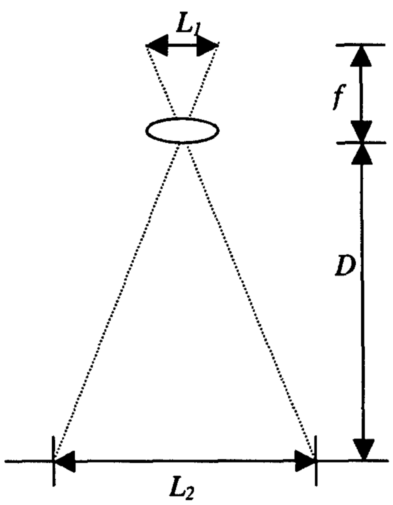
Table 15. Road intersection GCP data in latitude/longitude format, with Estimated Position Error.

LOCATION	DATE	TIME	LATITUDE (N DD MM SS.S)	LONGITUDE (W DD MM SS.S)	ALTITUDE	EPE
Orange @ Tucker	2002-06-06	12:53:00	45 57 23.8	77 23 13.0	162.6 m	±10.0
Orange @ Messer	2002-06-06	12:59:00	45 57 40.7	77 21 59.4	160.4 m	±8.2
Messer @ Veritable	2002-06-06	13:09:00	45 55 51.9	77 20 04.3	165.7 m	±7.2
Brindle @ Middle	2002-06-06	13:29:00	45 56 04.9	77 19 16.6	167.9 m	±11.6
Air Field @ X	2002-06-06	13:40:00	45 55 09.1	77 18 47.1	152.5 m	±25.8
Deluthier @ Middle	2002-06-06	13:55:00	45 58 58.1	77 21 43.5	151.1 m	±12.1
Waito @ River Rd	2002-06-06	14:26:00	45 58 13.0	77 19 06.1	121.0 m	±23.3

Note: The data in this table is a subset of the data in Table 14. The Estimated Position Error (EPE) is for all three axes.

Aerial Photography

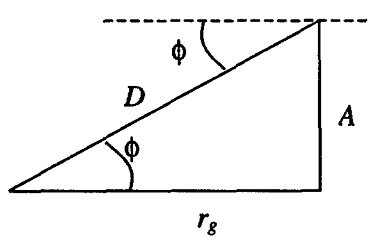
For optical cameras, the field of view, L_2, captured on film varies with the distance, D, from the scene being photographed [21]. This variation is dependent on two properties of the camera, namely the focal length of the lens, f, and the length of film, L_1, illuminated during an exposure. The relationship of these terms is given by



$$D/f = L_2/L_1$$

Figure 22. Geometry for optical photography.

For aerial photography of a target on the ground, D becomes the slant range to the target, which can be decomposed into an altitude, A, and a ground range, G, for a given depression angle, ϕ. Thus,



$$(L_1/L_2)f = D = A/\sin(\phi)$$

$$A = (L_2/L_1)\, f \sin(\phi)$$

Figure 23. Geometry for aerial photography.

Thus, by flying at a constant altitude along the desired bearing toward the target scene, the photographer can be assured of obtaining the correct field of view by aiming the camera at the desired depression angle and taking the picture only when the target scene becomes centred in the viewfinder.

Table 16. *Desired altitudes for acquisition of aerial photography. Calculated values of A are given in metres with Imperial approximations given in feet.*

L2	DEPRESSION ANGLE (ϕ)		
	30	**45**	**90**
100 m	76.4 m (250')	107 m (350')	153 m (500')
200 m	153 m (500')	216 m (710')	305 m (1000')

Raw Soil Moisture Readings

Table 17. *Soil Moisture data.*

Target	Time Delay	Soil Moisture	Date	Time
M109	27.9	15.8%	02-06-05	16:25:07
Left Front	27.1	14.7%	02-06-05	16:26:05
	27.2	14.9%	02-06-05	16:26:30
M109	25	13.0%	02-06-05	16:28:28
Right	25.6	12.6%	02-06-05	16:28:54
Front	25.7	12.7%	02-06-05	16:29:16
Grizzly	25.1	11.5%	02-06-05	16:34:32
Left Front	25.1	11.9%	02-06-05	16:35:00
	24.9	11.6%	02-06-05	16:35:33
Grizzly	23.8	10.1%	02-06-05	16:38:08
Right	23.7	9.9%	02-06-05	16:38:42
Front	23.7	9.9%	02-06-05	16:39:15
Box	22.1	7.7%	02-06-05	16:41:49
Truck	22	7.5%	02-06-05	16:42:21
Left Front	22	7.5%	02-06-05	16:43:16
Box	21.9	7.4%	02-06-05	16:43:47
Truck	22	7.5%	02-06-05	16:44:41
Right				
Front	22	7.5%	02-06-05	16:45:03
ARC	25.1	11.9%	02-06-06	12:45:52
Power	25	11.8%	02-06-06	12:46:26
Hog	25.7	12.7%	02-06-06	12:47:23
	24.1	10.5%	02-06-06	12:48:31
	25.5	12.5%	02-06-06	12:49:37
GPS/Met	24.2	10.8%	02-06-06	12:54:23
Station	22.3	7.9%	02-06-06	12:55:14
	24.2	10.6%	02-06-06	12:55:55
	22.7	8.5%	02-06-06	12:56:33
ARC	24	10.3%	02-06-06	12:59:27
Gemini	23.1	9.1%	02-06-06	13:00:10
	22	7.5%	02-06-06	13:00:46
	22.3	7.9%	02-06-06	13:01:21

Target	Time Delay	Soil Moisture	Date	Time
ARC	23.2	9.2%	02-06-06	13:04:36
Serafina	21.8	7.2%	02-06-06	13:05:09
	25.9	13.6%	02-06-06	13:06:05
	21.7	7.1%	02-06-06	13:06:46
	21.5	6.8%	02-06-06	13:07:40
Corner	22.3	7.90%	02-06-06	13:11:41
DREP	22.3	7.90%	02-06-06	13:12:35
	21.9	7.40%	02-06-06	13:13:21
	23.8	10.10%	02-06-06	13:14:08
Corner	26.4	13.7%	02-06-06	13:17:01
Andromeda	25.8	12.9%	02-06-06	13:17:41
	23.6	9.8%	02-06-06	13:18:19
	21.7	7.1%	02-06-06	13:19:01
Corner	24.1	10.5%	02-06-06	13:21:45
DREO	27.5	15.3%	02-06-06	13:22:15
	23.6	9.8%	02-06-06	13:23:02
	20.9	6.0%	02-06-06	13:33:41
	21	6.1%	02-06-06	13:24:13
Corner DREA	28.8	17.1%	02-06-06	13:26:55
	24.2	10.6%	02-06-06	13:27:43
	24.2	10.6%	02-06-06	13:28:36
	28.3	16.4%	02-06-06	13:29:16
	24	10.3%	02-06-06	13:29:58
Corner DREV	27.4	15.1%	02-06-06	13:32:41
	26.2	13.5%	02-06-06	13:33:16
	25	11.8%	02-06-06	13:34:09
	26.1	13.3%	02-06-06	13:34:47
ARC	24.5	11.1%	02-06-07	09:00:34
Power Hog	24.7	11.3%	02-06-07	09:01:06
	24.5	11.1%	02-06-07	09:01:37
	24.6	11.2%	02-06-07	09:02:09

Target	Time Delay	Soil Moisture	Date	Time
GPS/Met	22	7.5%	02-06-07	09:05:39
Station	31	20.2%	02-06-07	09:06:42
	29.9	18.7%	02-06-07	09:07:26
	23.8	10.1%	02-06-07	09:07:57
	25.1	11.9%	02-06-07	09:08:31
	23.8	10.1%	02-06-07	09:09:02
ARC	23.1	9.1%	02-06-07	09:15:42
Gemini	23	8.9%	02-06-07	09:16:12
	23.1	9.1%	02-06-07	09:16:48
	21.4	6.7%	02-06-07	09:17:19
ARC	22	7.5%	02-06-07	09:23:04
Serafina	23.1	9.1%	02-06-07	09:23:37
	25.8	12.9%	02-06-07	09:24:13
	22.3	7.9%	02-06-07	09:24:53
Corner	28.5	16.7%	02-06-07	09:28:46
Andromeda	27.1	14.7%	02-06-07	09:29:29
	23.9	10.2%	02-06-07	09:30:12
	22	7.5%	02-06-07	09:30:56
Corner DREP	23.3	9.4%	02-06-07	09:33:53
	23.4	9.5%	02-06-07	09:34:30
	22.9	8.8%	02-06-07	09:35:04
	23.2	9.2%	02-06-07	09:35:38
Corner	27.4	15.1%	02-06-07	09:37:58
DREA	23.9	10.2%	02-06-07	09:39:57
	25.5	12.5%	02-06-07	09:40:32
	26.2	13.5%	02-06-07	09:41:39
Corner	24.8	11.5%	02-06-07	09:44:26
DREO	23	8.9%	02-06-07	09:45:00
	24.1	10.5%	02-06-07	09:45:39
	23.8	10.1%	02-06-07	09:46:22
Corner	28.5	16.7%	02-06-07	09:49:18
DREV	30.3	19.2%	02-06-07	09:49:54
	27.6	15.4%	02-06-07	09:50:34
	27.6	15.4%	02-06-07	09:51:16

DRDC Ottawa Ground Event Logs

Table 18. June 6, 2002 Ryan English.

17:55	Iltis north from shed to Orange, west on Orange Road
18:42	Iltis north from Totalize to shed
18:47	Iltis north from shed to Orange, east (?) on Orange Road
20:03	MLVW circles shed
20:04	Iltis circles shed

Table 19. June 6, 2002 Lloyd Gallop (DREO Ground).

Line #	Start Line	End Line	Comments
1	17:07	17:17	No ARC's
2	17:34	17:39	All targets acquired.
3	17:51	18:00:15	17:55 – Iltus. All targets acquired
4	18:13:30	18:22	
5	18:26	18:34:30	All targets acquired.
6	18:43		Iltus going North at 20 Kph. Image "Poor Focus".
7	18:57:30	19:04	All targets acquired.
6	19:11:03	19:16:15	Repeat Line. All targets acquired.
8	19:27	19:34:30	19:31 - All targets acquired.
9	19:38:30	19:45	All targets acquired.
7	20:02	20:06	

Table 20. *June 7, 2002 Ryan English (DREO Ground).*

12:09	Explosion south of Gust Road	14:00	Start line 7
12:10	Explosion south of Gust Road	14:01	JetRanger stationary (on ground?) in NW DZ Anzio
12:15	Start line 1 (first contact with CV-580)	14:05	JetRanger moving
12:18	Targets acquired	14:06	JetRanger hovering in NW DZ Anzio
12:20	2 x MLVW arrive shed from Messer	14:08	JetRanger moving to hover/ground in N DZ Anzio
12:22	Beaver a/c of DZ Anzio	14:10	JetRanger moving, returns to helipad
12:25	2 x MLVW west on Totalize	14:12	Abort line 7, attempt to refly the line
12:30	2 vehicles west on Orange	14:18	JetRanger blades cease
12:31	Start line 2	14:25	JetRanger blades spinning
12:37	Targets acquired	14:28	Restart line 7
12:50	MLVW + Iltis convoy at shed	14:28	JetRanger departs helipad to east
12:53	Start line 3	14:31	Targets acquired
12:58	Targets acquired	14:39	Vehicle west on Orange
13:01	Beaver a/c over DZ Anzio NW to SE	14:41	2 x MLVW appear at west end of Totalize
13:05	DREV van from HSI cal site to shed to Totalize to angled cal site	14:48	Line 8 begins
13:09	Start line 4	14:54	Targets acquired
13:10	Beaver a/c over DZ Anzio N to S	15:02	Start line 9
13:15	Targets acquired	15:10	Targets acquired, north ARC not visible
13:25	Start line 5	15:15	Confirmed misalignment of Serafina (due to confusion reading compass)
13:27	2 X HLVW from shed to Messer	15:19	Line 10 begins
13:31	Targets acquired	15:23	Targets acquired
13:35	2 x HLVW + Iltis west on Totalize	15:29	Start line 11
13:39	Car east on Totalize	15:35	Prop a/c S to N over highway (?)
13:41	Start line 6	15:37	Targets acquired, CV-580 RTB
13:45	Convair spotted from Ground		
13:48	Targets acquired		
13:51	MLVW circles shed		
13:55	MLVW circles shed		
13:59	JetRanger blades spinning + take-off from helipad		

Table 21. *June 8, 2002 Ryan English (DREO Ground).*

08:45	Test drive GMTI @ 10 km/h	11:10:00	Lead-in line 5, GMTI @ 5 km/h
08:51	At PTT tower	11:15:15	Start line 5, light rain
08:55	Return to GMTI start	11:16:45	Image Acquired
09:21:30	CV-580 first contact, 10 NM to lead-in	11:20:05	End line 5
09:28:25	Lead-in for line 1, GMTI @ 10 km/h	11:31:25	Lead-in line 6, GMTI @ 15 km/h
09:32:20	3 x helicopters fly west across Clement Lake Road	11:36:25	Start line 6, moderate rain
09:34:20	At PTT tower	11:38:20	Image acquired
09:36:05	Start line 1, light rain	11:40:15	Report from a/c: north ARC fading
09:37:30	MLVW east across N part of Clement Lake Road	11:41:00	End line 6
09:38:25	Image acquired	11:42	Red 4x4 arrives at Clement Lake Road
09:39:00	3 x MLVW pass N along Clement Lake Road	11:46	Red 4x4 departs for Calibration Site
09:39	2 vehicles parked near PTT tower	11:54:50	Lead-in line 7, GMTI @ 10 km/h
09:41:00	End line 1	11:56:50	MLVW travels south on Clement Lake Road
09:44:20	MLVW north on Clement Lake Road	12:00:10	Start line 7, steady rain
09:53:30	Lead-in for line 2, GMTI @ 5 km/h	12:00:15	At PTT tower
09:59:05	Start line 2, light rain	12:02:35	Image acquired
10:00:15	Image acquired	12:05:30	End of line 7
10:03:35	End line 2	12:19:20	Lead-in line 8, GMTI @ 5 km/h
10:19:15	Lead-in line 3, GMTI @ 15 km/h	12:24:15	Start line 8, light rain
10:20:50	3 x helicopters fly west across Clement Lake Road	12:27:05	Image acquired
10:23:15	Start line 3, very light rain	12:29:20	End line 8
10:23	At PTT tower	12:30	Red 4x4 returns to Clement Lake Road
10:25:50	Image acquired	12:40:50	Lead-in line 9, GMTI @ 15 km/h
10:28:45	End line 3	12:43:30	At PTT tower
10:43:00	Lead-in line 4, GMTI @ 10 km/h (using 1st gear)	12:45:55	Start line 9, @ 15 km/h
10:49:20	At PTT tower	12:47:45	Image acquired
10:49:35	Start line 4, light rain	12:50:30	End line 9, CV-580 heads to "Extra" line
10:51:55	Image acquisition		
10:54:40	End line 4		

List of symbols/abbreviations/acronyms/initialisms

2CMBG	Second Canadian Mechanized Brigade Group
ARC	Active Radar Calibrator
ATD	Automatic Target Detection
ATR	Automatic Target Recognition
AZ	Azimuth
BRDF	Bi-directional Reflectance Distribution Function
CAMEVAL	Camouflage Evaluation
casi	Compact Airborne Imaging Spectrograph
CCD	Coherent Change Detection
CCRS	Canada Centre for Remote Sensing
CF	Canadian Forces
CFB	Canadian Forces Base
CFJIC	Canadian Forces Joint Imagery Centre
CP	Command Post
CR	Corner Reflector
CV-580	Convair 580
dB	Decibel
dGPS	Differential Global Positioning System
DLR	Director Land Requirements
DND	Department of National Defence

DRDC	Defence Research and Development Canada
DSSPM	Director Soldier Systems Program Management
DZ	Drop Zone
EC	Environment Canada
EO	Electro-Optical
FAR	False Alarm Rate
GCP	Ground Control Point
GMTI	Ground Moving Target Indication
GPS	Global Positioning System
GR	Ground Range
HSI	Hyperspectral Imagery
InSAR	Interferometric SAR
ISR	Intelligence, Surveillance and Reconnaissance
J2/GICI	J2 Geomatics Imagery and Counter Intelligence
LFSR	Land Forces Signature Reduction
MCE	Mapping and Charting Establishment
Pol-InSAR	Polarimetric Interferometric SAR
PolSAR	Polarimetric SAR
RCD	Royal Canadian Dragoons
RCHA	Royal Canadian Horse Artillery
RCS	Radar Cross Section
RDDC	Recherche et développement pour la défence Canada
ROC	Receiver Operating Characteristics
RTK	Real-Time Kinematic

SAR	Synthetic Aperture Radar
SLC	Single Look Complex
SFSI-II	SWIR Full Spectrum Imager II
SR	Slant Range
SWIR	Short-wave Infrared
TCR	Target-to-Clutter Ratio
TIR	Thermal Infrared
UTM	Universal Transverse Mercator
VNIR	Visible and Near-Infrared

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The CAMEVAL-2002 Land Forces Signature Reduction (LFSR) trial was conducted at the Canadian Forces Base (CFB) Petawawa in June 2002. For the LFSR trial, 27 military vehicles (primarily Leopard C2 tanks and Coyote reconnaissance vehicles) were deployed under forest canopy, along tree lines and in open field. A subset of the Leopards and Coyotes was deployed with a trial camouflage screen, another subset was covered with the current in-service camouflage screen, and a final subset was left uncovered. During the LFSR trial, Defence Research and Development Canada (DRDC) Ottawa and DRDC Valcartier acquired airborne and spaceborne Synthetic Aperture Radar (SAR) imagery and airborne Hyperspectral Imagery (HSI) data over the trial sites, and conducted extensive calibration and ground truthing activities in support of these acquisitions. This report documents the SAR and HSI data acquisition, ground truthing and calibration activities completed during the trial, thereby providing the foundation for any future analyses that use these multi-sensor data. This report also describes the five DRDC Ottawa and DRDC Valcartier analyses that were planned at the time of the trial.

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SAR, polarimetry, PolSAR, HSI, hyperspectral, camouflage, military vehicles, RCS reduction, ATD, target detection, ATR, target recognition, data fusion